

MINERS' NYSTAGMUS.

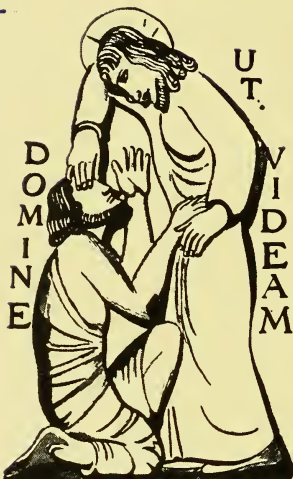
T. LISTER LLEWELLYN, M.D., B.S. (Lond.).

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MINERS' NYSTAGMUS.

Its Causes and Prevention.

— BY —

T. LISTER LLEWELLYN, M.D., B.S. (Lond.),

*Tyndall Research Mining Student of the Royal Society; Medical
Officer to the North Stafford Employers' Insurance Limited;
formerly Medical Officer to the Powell Duffryn
and Rhymney Coal and Iron Companies.*

With a Preface by

PROFESSOR J. S. HALDANE, F.R.S., M.D.,

And a Legal Appendix by

DOUGLAS KNOCKER, M.B. (Lond.), M.R.C.S., L.R.C.P., D.P.H.
Barrister-at-Law.

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MRS. TYNDALL.

The Tyndall Research Mining Studentship of the Royal Society was founded in 1910 to carry out the wish of Mrs. Tyndall, the widow of Professor Tyndall, who gave the sum of £1,000 to the Royal Society to be utilised in any manner which would conduce to the benefit of the miner either physically or intellectually—his safety, for example, or his health.



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Preface.

THE importance of this book in its relation to mine management and medical work among miners is evident from the title, and Dr. Llewellyn needs no introduction to those who are already acquainted with the subject, but I have willingly agreed to his request that I should write a short preface. It is a pleasure to me to be associated with him in laying before the public the results of his researches, with the value of which I am greatly impressed.

The serious eye trouble known as "miners' nystagmus" has been recognised for about fifty years; but full and exact study of the conditions which cause it has hitherto been lacking. Three years ago, in accordance with a wish expressed by her late husband, Professor Tyndall, F.R.S., Mrs. Tyndall placed in the hands of the Royal Society a sum of money for the purpose of furthering scientific research on "improvements in mining and in the lot of the miners." In this subject Tyndall, who held the chair previously occupied by Davy and Faraday, and served on the Royal Commission on Mines of 1879, was deeply interested. Dr. Llewellyn, who proposed to study the causes of miners' nystagmus, and who was specially qualified for the work by his acquaintance with both ophthalmic science and underground mining conditions, was appointed in 1910 as the first Tyndall Research Student. Summaries of part of his results have already appeared in papers by him in the *Proceedings of the Royal Society* and the *Transactions of the Institution of Mining Engineers*; but the present work contains a full and systematic account of the whole subject.

Perhaps the most important conclusions to be drawn from the evidence detailed in the book are, firstly, that whatever other causes may be contributory, miners' nystagmus is due to deficient lighting, more particularly to the very imperfect light given by the present types of safety lamp; and, secondly, that by better, and quite practicable, means of illumination the disease can be almost completely, if not completely, prevented.

That the occurrence of miners' nystagmus is closely connected with defective illumination has already been maintained by several writers—particularly, in this country, by Dr. Court, of Staveley; but other eminent authorities have taken an opposite view. The statistical and other evidence collected by Dr. Llewellyn, and his thorough quantitative examination into the actual illumination at the working face with different lights, have rendered the whole subject intelligible on its practical side. The extraordinary deficiency in the illumination given, under actual working conditions, by the safety lamps at present in use will come to mining engineers as something of a revelation; and this, I have no doubt, will act as a powerful stimulus to the introduction of better lamps, whether electric or dependent on combustion.

There is now every reason to hope that in the course of a few years miners' nystagmus, with all the mental suffering and pecuniary loss which it entails, will have practically disappeared. Should this hope be fulfilled, the work of Dr. Llewellyn, and of those who have aided him in his investigations or preceded him in part of them, will be abundantly repaid.

J. S. HALDANE.

Oxford, November, 1912.

Author's Preface.

THIS book is the outcome of a research undertaken when the author was Tyndall Research Mining Student of the Royal Society, and whatever merit it contains is due to the ungrudging help given by the members of the Mining and Medical professions.

I realise to the fullest extent that without this help, so freely given, I should have been quite unable to carry on the investigation, and also that the help was not given to me personally but for the "cause." Many of my helpers wish to remain anonymous, and their names will not appear.

Dr. Haldane has throughout given me the most valuable assistance and advice, and has very kindly written a short preface to this book. The Powell Duffryn Steam Coal Company and the Rhymney Iron Company, through Mr. E. M. Hamm, Mr. N. Phillips, and Mr. Rutherford, have given me every facility. To the members of the South Wales Mutual Indemnity Society, of the Midland Indemnity Society, of the South and North Staffordshire Indemnity Societies, and of the Yorkshire Indemnity Society, I am deeply indebted and offer my best thanks.

I have received valuable help also from the following gentlemen :—Dr. W. E. Garforth, Mr. Binns of Derby, and

Mr. Douglas Smith of Birmingham. Mr. Price, the manager of the Elliot Collieries, New Tredegar, has given me great help with my underground work, and also in work which I have carried out at the New Tredegar Rescue Station, in which I was also assisted by Mr. Kitto, the superintendent of the station.

I have also to thank the following medical gentlemen:—
Dr. Hughes, of Blackwood; Dr. Elworthy, of Ebbw Vale; Drs. W. and A. Martin, Leighton Davies, of Cardiff; Dr. Hislop, of Wrexham; Dr. Leary, of Alfreton; Dr. Wood, of Wakefield; Dr. Buncle, of Pontefract; Dr. Nicholson, of Leeds; Dr. Symes, of Chesterfield; Drs. Kerr and Emerson, of Sheffield; Dr. Gray, of Mansfield; Dr. Morris, of Mardy; Dr. Robson and Dr. Bird, of Penarth; Dr. Thomas and Dr. Phillips, of Ystard; Dr. Morris, of Tylorstown; Dr. Richards, of Risca; Dr. Astbury, of Aberaman; Dr. McGhie, of Merthyr Vale; and Dr. Wood, of Bridgend.

Dr. Hughes, of Blackwood, has read through my proof and has given me much help by pointing out obscure passages and suggesting alterations in parts of the manuscript.

Mr. A. P. Trotter very kindly suggested the alterations necessary in his photometer before it could be used underground, and has given me much assistance with my photometric work.

Mr. Wright, of Pengam, has kindly lent me some specimens of the various mineral ores.

I must also acknowledge help from the Government Grant Committee of the Royal Society towards the expenses of my photometric work.

Professor Ernest Jones, of Toronto, has given me much help in the section on "The Mental Factor as a Cause of Incapacity."

My thanks are due to Mr. Thompson for his drawings in the introduction and of my safety lamp.

Mr. Douglas Knocker has kindly written the legal appendix.

I am greatly indebted to my publishers (The Colliery Guardian Company Limited) for the way in which they have produced the book, and to Mr. Allan Greenwell (the editor of the *Colliery Guardian*), who has personally interested himself in the book, and to whom my best thanks are due for many valuable suggestions, among which may be mentioned the introduction and the glossary.

The book has been written both for the Mining and for the Medical professions, and this will explain on the one hand the brief descriptions given of mining operations, and on the other the definitions of medical terms.

The statistics are based on the examination of 600 consecutive cases.

All the photographs, with two exceptions, have been taken by myself, and in every instance no attempt was made to pose the subjects. The men were allowed to assume their natural attitudes without any remark or suggestion on my part.

The Tyndall Studentship was instituted to assist research, having as its object the promotion of the physical welfare of the miner; and I shall be well pleased if this investigation will help in any way to improve the conditions of work of an industry employing over one million men.

T. LISTER LLEWELLYN.

November, 1912.

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Description of the Eye.

THE eye is an almost spherical globe which is hung in the orbit and connected to the brain by a large nerve called the optic nerve. The front part of this globe, the cornea, is transparent and allows the rays of light to enter the eye. Behind the cornea and resting against the front surface of the lens is the coloured muscular diaphragm known as the iris. The aperture in this diaphragm is known as the pupil and varies in size according to the amount of light present. The lens is a transparent body which brings the rays of light to a focus on the internal membrane of the eye, known as the retina. The lens is slung in a tense capsule and its shape can be altered by muscular action. The alteration consists in making it more convex, or, in other words, more powerful. The retina is very complicated in structure, and consists of several layers. There is an outer layer of cells containing pigment and a layer of rods and cones. The other layers are not so important. These rods and cones are very important and are supposed to be the organs which enable us to perceive light. The rods are most numerous over the periphery of the retina, and are absent from the central part known as the fovea. The cones are present in large numbers at the fovea, and are found through other parts of the retina in smaller numbers. The fovea is that part of the retina which is brought into play when we look directly at anything; it is the part of the retina opposite the central points of the cornea and lens.

The muscles of the eye are supplied by the third, fourth and sixth cranial nerves, and these nerves have their nuclei or centres in the mid-brain.

Each eye has six muscles, the internal and external recti, the superior and inferior recti, and the superior and inferior oblique muscles. The internal and external recti muscles move the eye

inwards and outwards, and their actions are comparatively simple. The superior and inferior recti move the eye upwards and downwards, but they also rotate the eye as well. The oblique muscles cause rotation of the eyeball, with accompanying movements of elevation and depression.

The ocular movements are always bilateral, and it is very important to remember that no simple movement, except that of movement inwards and outwards, can be made without the combined action of several muscles, and that this result is brought about by cerebral co-ordination.

If there is marked weakness of any one of the ocular muscles an obvious squint is produced. In some cases, however, the weakness is less marked, and the squint is only brought out by special tests. The squint in these cases is spoken of as a latent deviation of the eye, or heterophoria. If, for example, the muscles which elevate the eye are weak, there should be a latent deviation of the eyes on looking upwards. This condition is known as hyperphoria. These latent deviations can only be brought out by divorcing the binocular image produced by the two eyes by placing a strong prism in front of one eye. To take a concrete instance:—It has been stated by Snell and others that there is a myopathy or weakness of the elevator muscles of the eye in miners' nystagmus. If this were so, latent deviation, or hyperphoria, on looking upwards, could be demonstrated by appropriate means. Reid has, however, shown that no such deviation exists (*see* page 31). The inference is that there is no weakness of the individual elevator muscles compared with the other muscles. The movements of elevation, as distinguished from the movements which might be produced by the elevator muscles if they could act individually, are weak in miners' nystagmus. It must be pointed out again that in all ocular movements the muscles do not act singly, and also that each muscle has several actions. Maddox, for instance, describes the action of the superior rectus as follows:—"The superior rectus elevates the cornea, intorts the eye because its insertion is 'superior' and adducts it

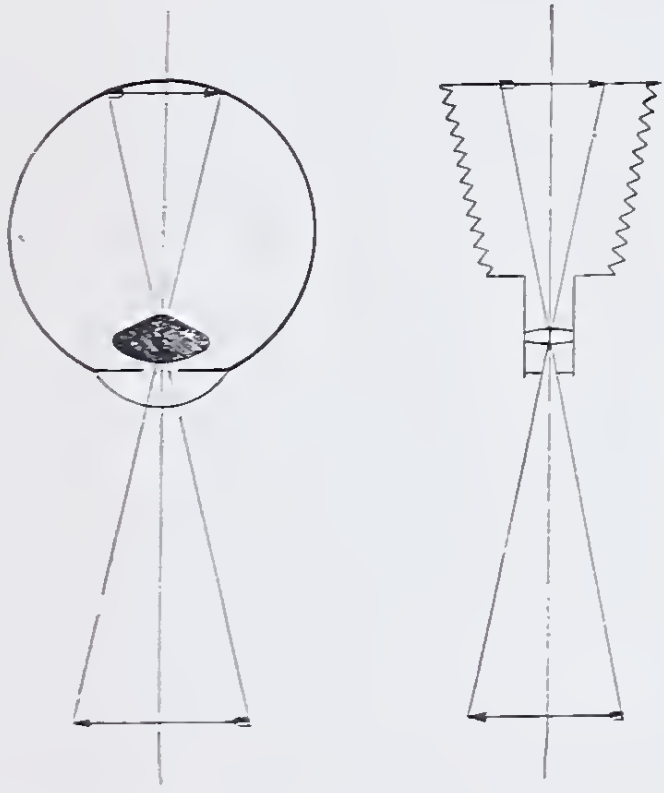


FIG. 1.—THE EYE AS AN OPTICAL INSTRUMENT.

A diagram to show the similarity between the eye and a photographic camera.

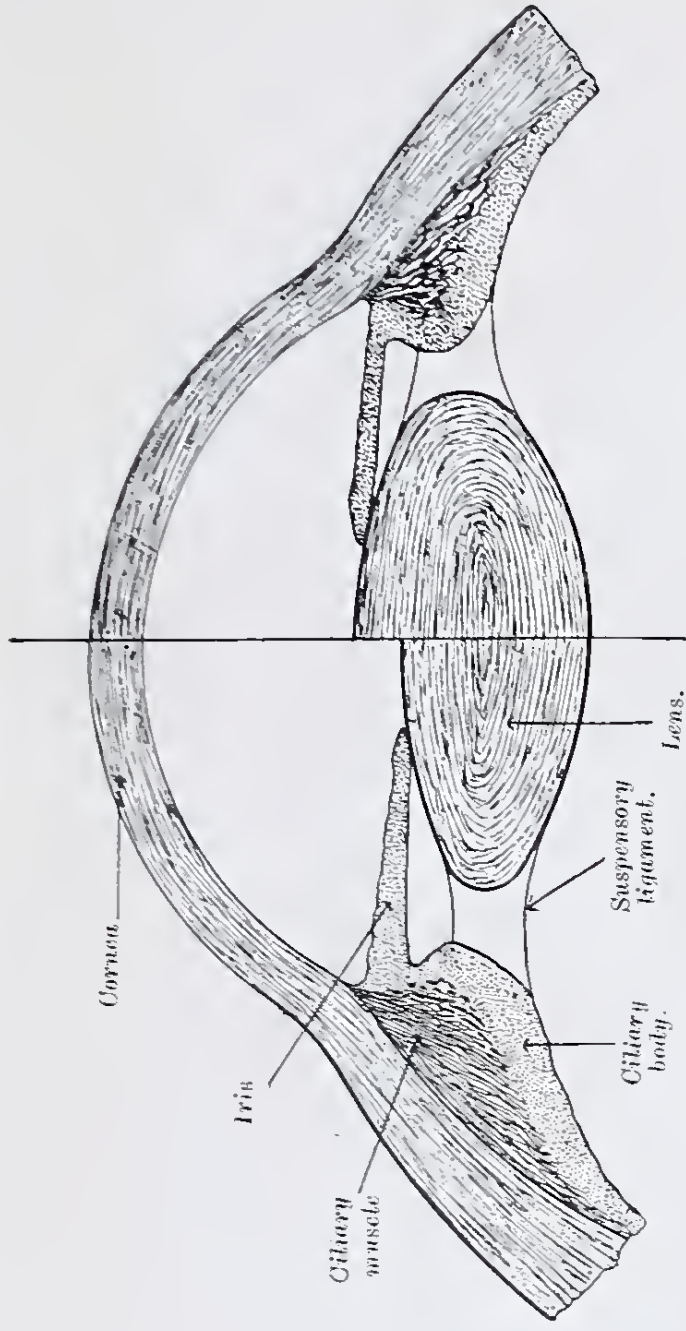
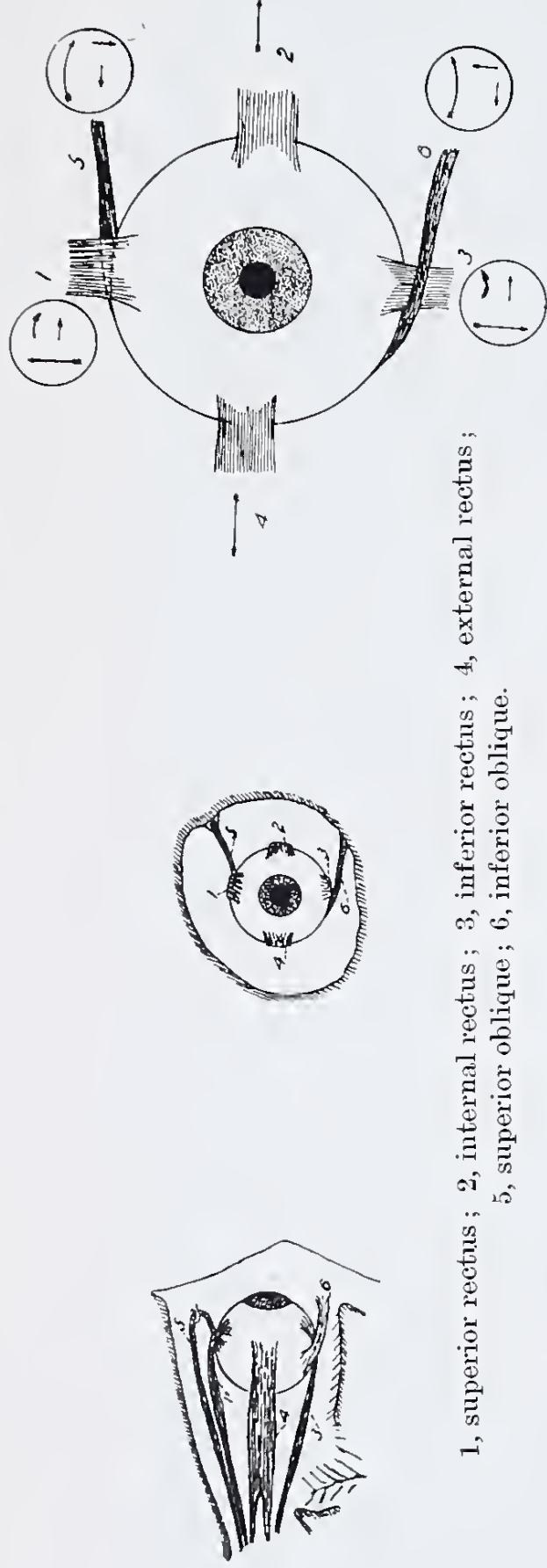


FIG. 2.—DIAGRAM TO SHOW THE CHANGES IN THE LENS DURING ACCOMMODATION. (Not drawn to scale.)

On the left-hand side the eye is shown at rest with the fibres of the ciliary muscle relaxed; on the right side the ciliary muscle has contracted and drawn the ciliary body forward. The tension of the suspensory ligament of the lens is relaxed, and the lens becomes thicker and more powerful. The suspensory ligament is shown as a thin membrane stretching between the lens and the ciliary body.



1, superior rectus; 2, internal rectus; 3, inferior rectus; 4, external rectus; 5, superior oblique; 6, inferior oblique.

FIGS. 3, 4, AND 5.—THE OCULAR MUSCLES.

Three diagrams of the right eye are shown. The first (fig. 3) is a representation of the muscles from the side with the outer wall of the orbit removed. The diagram is modified from Quain. The second diagram (fig. 4) shows the muscles from the front, and is a modification of a diagram after Merkel and Kallius. The third (fig. 5) is original, and in it an attempt has been made to show the action of the muscles by the help of arrows. The large arrow gives the primary action, and the smaller arrows the secondary actions. The description given by Maddox has been followed. Maddox says that the action of the muscles is as follows:—

- Superior rectus. Elevation, intortion and adduction.
- Inferior rectus. Depression, extortion and adduction.
- Superior oblique. Intortion, depression and abduction.
- Inferior oblique. Extorsion, elevation and abduction.
- External rectus. Abduction.
- Internal rectus. Adduction.

- Intorsion is rotation of the eyeball towards the nose.
- ↗ Extorsion is rotation of the eyeball towards the temple.
- Adduction is movement of the eye towards the middle line of the body
- ← Abduction is movement of the eye away from the middle line of the body
- ↑ Elevation is movement of the eye upwards.
- ↓ Depression is movement of the eye downwards.

because it is inserted into the anterior hemisphere." Three separate actions for one muscle.

In emmetropia, or normal vision, parallel rays of light are brought to a focus on the retina without the use of accommodation. In myopia, or short sight, the eye is too long, and parallel rays are brought to a focus before they reach the retina, and consequently a blurring of the image results. In the same way in hypermetropia, or long sight, the eye is too short, and parallel rays are brought to a focus behind the retina. Here accommodation may be brought into play and parallel rays focussed accurately. A long-sighted person then can see things at a distance quite well, but there is a considerable strain brought about by the continual use of the function of accommodation. In astigmatism the horizontal and vertical curvatures of the cornea are unequal, and as a result it is impossible to obtain a correct focus for both sets of rays at the same time. Everybody is familiar with the "sunrise" diagram which is always exhibited in opticians' windows. It consists of lines radiating from a common centre. In astigmatism the horizontal and vertical lines cannot be seen clearly at the same time. It will readily be seen that this condition causes a great strain on the eyes, which have continually to focus the various parts of the object separately in order to try to obtain a clear image.

Hypermetropia, myopia and astigmatism, are all included in the term ametropia or defective vision. The amount of defective error or error of refraction present, is expressed in terms of that lens which enables the eye to bring parallel rays to an accurate focus on the retina without the aid of accommodation. A lens of one diopter, shortly written 1D, is a lens of 1 metre focal length. If such a lens corrects the patient's error he is said to have an error of refraction of 1D. Short-sighted men require concave or minus lenses, and a minus sign is placed before the figure, *e.g.*, - 1D is a concave lens of one diopter. Long-sighted men require a convex or positive lens and a plus sign is placed before the figure, *e.g.*, + 1D. In astigmatism, a cylindrical lens is necessary, and

the strength of the lens is given in the horizontal and vertical axes

thus— $\frac{+1}{+}$ + 1.5. In the formula given there is one diopter of hypermetropia in the vertical axis and one and a-half diopters in the horizontal axis.

Accommodation.—The focal length of the lens of the eye can be altered by the action of the ciliary muscles so as to make the observation of near objects easy. This alteration is known as accommodation, and we are always using a certain amount of accommodation, unless we are shortsighted, whenever we look at any near object. Excessive accommodation produces a strain on the eyes and defeats its own aim. Strong accommodation is accompanied by convergence of the eyes, and the balance between these two actions may be upset. Strong accommodation and convergence are used normally when an object is being closely examined while it is held in the hand. If a man looks at an object 3 ft. away, and by reason of strong accommodation causes excessive convergence, this convergence, which is a help in the first instance, becomes a drawback in the second, as the normal relation between the position of the eyes and the amount of accommodation is not maintained.

The amount of vision, or the visual acuity, possessed by a man is measured by asking him to read a card containing letters of varying sizes arranged in rows; each row should be read at a certain distance. If the man can read the letters in the six metre line at six metres distance, then he is said to have normal vision or to see 6/6. If, however, he can only read the eighteen metre line at six metres distance, then he is said to see 6/18.

When light falls on the retina, a decomposition of the pigment, visual purple, is brought about. This visual purple acts on the rods and cones through its chemical decomposition in much the same way as light acts on a photographic plate. If a frog is killed after being kept in the dark for a long time and before it is exposed to light, the pigment granules are seen in the bases of the pigment cells of the retina. If, however, the animal is killed after

exposure to bright sunlight, the pigment granules will be seen extending into the rods and cones, leaving the pigment cells almost empty. This shows that light decomposes the pigment, and that it is built up in darkness. The inference is that through this decomposition the perception of light is possible. A division of function between the rods and cones has been described; the rods are supposed to be the organs most sensitive to dull illumination and the cones to the perception of bright light (*see* p. 113).

If we wish to examine any object closely we hold it a short distance in front of and below the level of our eyes. In this position the image falls on the fovea, and the eyes are less liable to stray from the point fixed than in any other position in which they may be placed. This is direct fixation. If the object is fixed with the periphery of the retina or with the corner of the eye the image is less defined and the tendency to movement of the eye is much greater. This is indirect fixation. The peripheral part of the retina is more sensitive to dull illumination, and consequently this part of the eye is used more in the coalmine than on the surface. The result is that a tendency to movement of the eyes is set up, and this tendency has a great influence in the production of nystagmus.

The eye acts in the same manner as a photographic camera; the lens, diaphragm, and aperture, of the one may be compared with the lens, iris, and pupil of the other. The photographic plate represents the retina, and its development may be compared with the chemical changes undergone during the decomposition of the visual purple.

CHAPTER I.

General Description of the Disease.

MINERS' nystagmus is an occupational disease of the nervous system which is confined to workers in coalmines. The chief symptom and physical sign is a rotatory oscillation of the eyeballs, which prevents the miner from accurately fixing anything towards which his vision is directed. I have compared the result to a cinematograph exhibition, in which the pictures have not been taken rapidly enough to produce a continuous image. A sufferer writes (59):—"The dancing of objects before the eyes somewhat resembles the quivering motion of the figures observable in a faulty cinematograph exhibition, only not so rapid, of course, and instead of the objects moving vertically as do those of the cinematograph, they seem to be revolving."

DESCRIPTION OF THE SYMPTOMS.

The first and most generally observed symptom is failure of sight, which is most marked at night time or when the sufferer is called upon to perform the more skilled part of his work. He cannot notch timber well, and fails to drive his wedge or strike with his pick the exact piece of coal aimed at. He next complains that the lamps dazzle his eyes, that they appear full of flame, and sooner or later that all surrounding objects in general, and the lamps in particular, are going round and round. In some cases trouble is only noticed on the journey to or from the coal face, when the dancing of the lamps of his fellow workmen, walking out in front of him, produces such giddiness that the man is obliged to sit down "to let the lamps go by." The classical symptom of movement in the surrounding objects is the most characteristic of all. Like all other symptoms, it is more marked after excitement or exertion, and is sometimes only brought out by the patient assuming a special position—a fact of which he is well aware. When once produced, the movements can almost always be con-

trolled if the man looks downwards and inwards or covers his eyes with his hands for a few minutes.

HEADACHE, varying from slight pain between the temples to attacks of extreme severity, is present in many cases. It is increased by sunlight, and in common with all the other symptoms, by stooping or exertion. One of my cases was free from headache when his eyes were moving, and suffered when they were at rest. This, however, is most unusual, and was only present in this one case. The headache is generally described as a pain shooting through both temples, or it may be referred to the back of the head or nape of the neck.

TEMPORARY GIDDINESS on stooping or exertion is common, but in some cases giddiness to the extent of ataxy is present. One of my cases is only able to cross a room with the help of the furniture.

NIGHT BLINDNESS.—Most sufferers complain that they are worse at night, or, as they say, "between the two lights" or "in the twilight." This is often an early symptom, and the onset of the disease is first noticed by trouble at night. "I am all right except in the night time" is a most common saying. Many patients are quite unable to go out alone at night, and I have heard of some who had to be brought home from the pit top by their wives at the end of a day's work. One of my own cases had to be led to work from the pit bottom, but managed to earn a living at the coal face. The presence of this symptom of night blindness, though denied by eminent authors, is, in my opinion, one of the most characteristic of all. Snell (106) says it is very rare, and Romi  e denies its existence; this is the one point on which these authors agree. Dransart (35) says it occurs in 5 per cent., Butler in 60 per cent. (11), and Court (22) in 77 per cent. Leaving out my latent cases, I found it in my series in 74.9 per cent. My figures therefore agree closely with those of Court. Different authors have apparently taken different views of the definition of night blindness. I have taken it to mean men who suffer much more by night than by day. In some of my cases the night blindness has been complete.

PHOTOPHOBIA, or *dread of light*, is common, and was found in 210 of my cases. The men walk about on a bright day with their caps pulled well down over their eyes and cannot stand a bright light of any kind; this makes retinoscopy impossible in

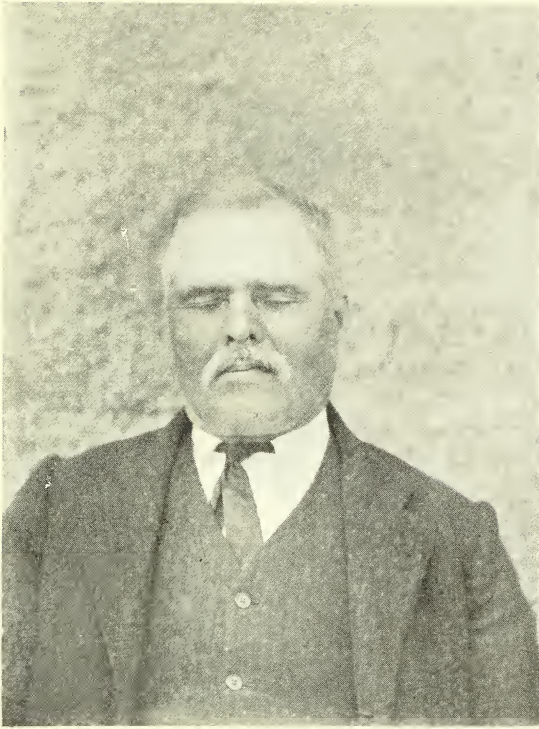


FIG. 6.—AN EXTREME CASE OF PHOTOPHOBIA.

This man always goes about with his eyes practically closed, as shown in the photograph.

many cases. Many wear smoked glasses when out in the sunlight, and get relief in this manner

PHOTOPSIA is very rare, and only two of my patients have complained, one of coloured rings around the lamp flame and the other of a ball of fire before his eyes, even in the dark.

DIPLOPIA, or *double vision*, is also very rare. It was present in two cases only (157, 266).

Mental Symptoms.

Well marked cases are very liable to fits of depression, several have cried during my examination, and two (1, 8) have expressed suicidal intentions. One man told me, "This is only existing, it's not worth calling living." (See p. 22.)

TABLE 1.—ANALYSIS OF SYMPTOMS IN 482 MANIFEST CASES.

	No.	Per cent.	Marked.	Very marked.
Movement of objects	465	96·4		
Headache	404	83·8	45	16
Giddiness	396	82·1	45	8
Night blindness	361	74·9	4	
Photophobia	224	46·4	10	

VARIETIES OF THE DISEASE.

There are two distinct varieties of the disease. In the first the symptoms are absent or latent, and the man apparently suffers no disability and is unaware that he has nystagmus; in the second the man is more or less incapacitated and is aware that his eyes are affected.

TABLE 2.

Latent	118
Manifest	482

The manifest group may further be divided into the slight form, where little disability is felt and the man is able to continue his work; the ordinary form, where the man is unable to work underground; and the severe form, where incapacity is complete. The ordinary case of nystagmus can do any kind of work on the surface which does not involve much stooping.

*Relative Frequency.**—It is impossible to give the exact proportion of men suffering from the slight form of the disease. All my manifest cases belonged to the second group with the exception of 10 per cent., which should be included under the severe form.

CASES ILLUSTRATING THE DIFFERENT TYPES OF THE DISEASE.

The Latent Form.

(58) Ostler. One day when examining some horses in the pit for nystagmus and finding no sign of the disease, I turned to one of the ostlers present and told him I should have to examine him. He laughingly agreed and said that he had had no trouble. On examination marked nystagmus was present. The man is still working underground without any trouble. I did not tell him the result of my examination.

The Slight Manifest Form.

(33) Collier 46, underground 34 years, still working. "I can work as well as anybody. It is only when I have a cold in my eyes that they shake, and then I put a cold handkerchief on my forehead." Nystagmus well marked.

The Ordinary Form.

(51) Collier 35, underground 20 years. "Three weeks before I failed my eyes became so bad I could not do anything." He was idle three weeks and then returned to work on the surface, where he remained for four months. He then returned to the coal face and is still working underground.

The Severe Form.

This case presents so many interesting features that it will be described in full.

Case (1), a sturdy, well-built collier, age 34, with 20 years' underground work. Almost all his time has been spent on the coal, and for the last few years he has been working in narrow seams, 2 to 3 feet, in a hot and dusty pit which was not well ventilated. The pit was closed shortly before his failure. He has always worked with safety lamps. On August 26 he had a slight blow on the top of his head from a stone. He resumed work on August 31, and was suddenly seized with blindness while at work and had to be led home. He had never had any symptoms before. On examination he showed violent rotatory nystagmus, even with the eyes in the horizontal position. He

* See page 15.

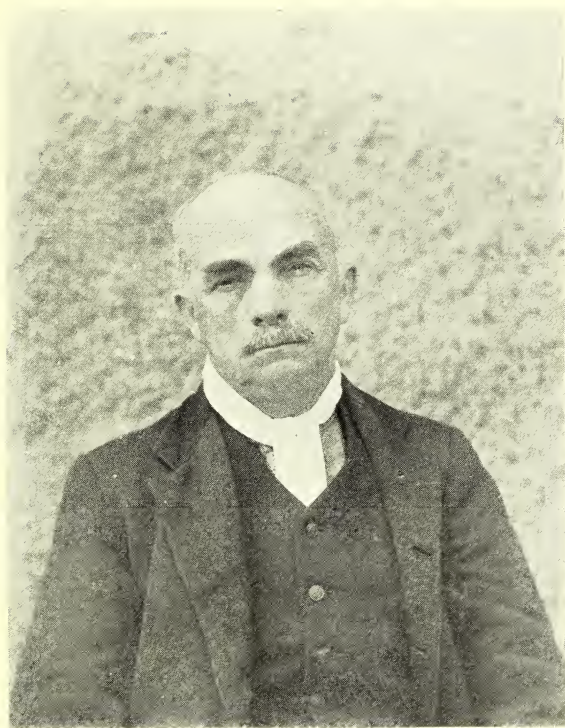


FIG. 7.—PHOTOGRAPH INTENDED TO SHOW THE
MARKED DEPRESSION WHICH IS SOMETIMES
SO NOTICEABLE IN PROLONGED CASES.

had severe headache, ataxy and marked photophobia. He became very depressed and drank heavily. He showed no improvement for months, and on more than one occasion expressed suicidal tendencies. He showed marked nystagmus at the end of 18 months, and at that time accepted a large lump sum from the company in settlement of his claim. I met him about a month after this and found that he was working underground again without ill results. He told me that he got well at once by following a line of treatment which must be described in his own words:—"I have been taking Dr. Williams's Pink Pills for Pale People for the last three weeks, two after each meal, with threepennyworth of gin each time. I came well at once."

His vision was then 6/6, and I was unable by any test to obtain any sign of nystagmus.

The case is a most interesting one from several points of view:—

(1) Conditions of work. Lately much holing on the knees and side, narrow seams, hot and dusty with bad ventilation, safety lamps used throughout.

(2) Suddenness of onset and relation to accident. Absence of any previous symptoms.

(3) Severity of the attack with bad result of alcohol.

(4) Patient was very fair and had blue eyes, vision at first very limited, afterwards 6/6.

(5) Sudden recovery. I do not think the man was a malingerer, as he repeatedly asked for work, which the company, acting on my advice, refused to give him.

An attempt has been made lately to subdivide miners' nystagmus into the ordinary form, in which movement of the eyes always occurs, and a neurotic form, in which the presence of movement is not necessary for diagnosis. Several of the speakers at the Oxford Ophthalmological Congress, 1912, laid stress on this point. I think, myself, that a neurosis is often grafted on to nystagmus, and that in these cases the prognosis is bad, but in all of my cases, with one doubtful exception, nystagmic movements were present.

Case (106). Collier age 25, underground 11 years. This man fell off a scaffold (underground) fifteen feet high on to his head. He sustained very extensive scalp wounds and a fracture of his skull. During convalescence he suffered from marked giddiness, headache, and inability to read. He was very nervous and had marked tremor of the hands and head. He was unable to look at any light and complained that everything he looked at was blurred. When asked to fix any point his eyes rolled up under cover of the upper lids (this

sign is frequently seen in nystagmus) and twitching of the eyelids was also present. The movements of the eyes were irregular, but no true rotatory nystagmus was present.

I considered the case to be primarily one of traumatic neurosis, with some symptoms of nystagmus grafted on. See also case (6), page 7.

I think, then, it would be more correct to say that a certain number of cases show marked signs of neurosis, than that a neurotic type of the disease exists.

Several cases of the association of nystagmus with other conditions are scattered through medical literature; thus Cocking (17) describes a case of nystagmus with spasmodic torticollis, and Bramwell (7) a case of a miner who had palpitation, profuse sweating, tachycardia, and arrest of the heart-beat, on taking a few deep breaths, in addition to nystagmus. He describes the case as one of nystagmus with pulmonary heart disease. Snell devotes a few pages (pages 70-75) of his book to a description of cases of torticollis associated with nystagmus.

THE COURSE OF THE DISEASE.

The course of the disease may be divided into three periods:—

Period of onset.

„ „ total incapacity.

„ „ recovery.

Period of Onset.

The onset of the disease is generally gradual, and an interval of 12 months often elapses between the first symptom and failure to work. In my cases the average interval was found to be 10·93 months. The man gradually realises that his sight is failing and that he is unable to perform his work properly. This incapacity gradually increases and the man has to lose a day or two, or take a week's rest. Some of the best workers struggle on in the hope that their symptoms are temporary, but they are sooner or later obliged to leave the pit. Some men have a most pathetic story to tell of their heroic struggle against the disease.

Case (29). Collier age 58, underground 40 years. "Up to the last two years before I failed I had no trouble with my eyes and always earned good money. During the last two years my eyes got weak, but I struggled on, hoping things would mend. I lost days and days,

and on times a week. At the end it was not safe for me to go to the face without the help of another man. I could not recognise anybody, and had to walk in with my lamp held behind my back. When I was at the face I had to test the roof in the dark. I could always tell by the sound if it was safe. My wages fell to a pound a week, and the manager stopped me at last and told me that it was not safe to allow me to work any longer. If I could only have known before, I might have saved my eyes." The man is still idle, 18 months after leaving the pit.

Most cases fail within 18 months after the first symptom appears, but there are some men in whom the disease remains quite stationary. I was told by one man that he had nystagmus for 20 years and had not lost any time.

In some cases, however, the onset is startlingly sudden, and a few will be quoted. The most interesting is a case (6) where nystagmus followed immediately on the nervous shock the man sustained in the Darran explosion (55). The man was a collier aged 38, who had never had any trouble with his eyes. He was in the pit at the time of the explosion, and was found by the first rescue party in a dazed condition and suffering from superficial burns about the head. I noticed nystagmus on the third day after the explosion, and the man developed marked symptoms of neurasthenia which kept him idle for eight months. He finally resumed work on the surface, and is at present at his old work underground. Eighteen months after the explosion he complained of marked symptoms, but no nystagmus was found on examination. His vision at that time was 6/6, and he had no error of refraction. The case is further interesting in that the man had always worked in a naked light colliery. In my series 57 cases were attacked suddenly; a few brief notes will be given.

Cases Illustrating the Sudden Onset of the Disease.

(1) "I became blind in the work and had to be led home. My eyes were quite well before." *See* page 4.

(124) "While at work on February 22 something came over me and I became almost blind at once. I was quite unable to recognise anybody and had to be led out."

(137) "While holing in the coal a blister exploded in my face, my eyes got bad at once and I had to be led out."

(142) "My eyes went bad at once after lifting a tram."

(144) Symptoms only two weeks before failure.

(190) "On March 1, 1911, I was buried under a fall, my eyesight failed at once. I had no trouble before."

(245) Septic corneal wound left eye, followed at once by symptoms.

(256) Blow on left eye, followed at once by symptoms.

(260) Onset very sudden.

(10) This case is very interesting. I saw the man on November 8, 1910, for an injury to his back, and noticed that he had marked nystagmus. He was at the time unaware of this, and told me that he was as good a collier as anybody. While still in receipt of compensation for the injury to his back he went, on the evening of December 5, to chapel. While there he suddenly became very giddy, and had to be led home. From this time he had most marked symptoms of nystagmus, although I did not notice any difference in the physical signs. He assured me that he had had no symptoms until that evening, and that he had been able to follow his work without any trouble.

This case illustrates my view that the higher centres are able at first either to ignore the irregular impulses coming from the periphery, or by a greater effort to counteract them. A time comes when this control is no longer possible, and then subjective symptoms arise.

A slight accident, ill-health, or over-exertion can upset the balance and convert a latent into a manifest case.

The Period of Total Incapacity.

Some men after failure are able to work on the surface at once, but others require a rest of two or three months. In this stage of the disease the symptoms of headache, giddiness and night blindness are marked, and may be taken as an index of the severity of the attack. In winter the prognosis is worse than in summer, and recovery may be delayed until the arrival of spring. Total incapacity may last from one to six months, and passes gradually into the period of recovery. Often, however, the man is able to work on the surface long before any work is offered him, and this stage is consequently unduly prolonged. Some of the most marked cases never recover, and remain permanently unable to produce work of any marketable value to the colliery owner.

The Period of Recovery.

In this stage the man is able to do any work on the surface, and the sooner he starts the better the prognosis. This stage lasts from six to twelve months, but here again will be found cases which make no further progress and remain permanently unfitted for underground work. In the later stages of this period the man



FIG. 8.

TWO PHOTOGRAPHS OF THE SAME PATIENT.

This man shows in a marked degree the backward position in which the head is often thrown in severe cases. In this case, which is one of great severity, the head is held obliquely as well. Note the way in which the cap has been pulled down over the eyes to keep the light out

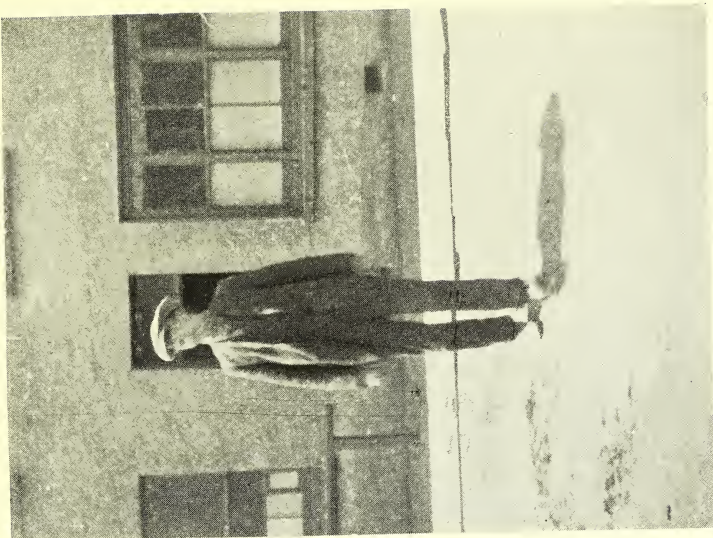


FIG. 9.

is able to work underground as a labourer or assistant repairer. The stage of cure is reached in many cases, and the man is able to return to his own work at the coal face. Relapse is, however, common, and with each relapse the prognosis is gloomier.

PHYSICAL SIGNS OF THE DISEASE.

General.

In many cases miners' nystagmus may be diagnosed at a glance. The head is thrown back, often obliquely, the cap is pulled down well over the eyes, and the man looks at you from under his drooping eyelids. In some cases the gait is ataxic, especially after turning quickly or stooping. On closer examination a head tremor may be seen or felt, and a rotatory oscillation of the eyeballs brought out by asking the man to look at your finger held above the level of his eyes. The severe cases often exhibit marked general changes, such as weak action of the heart, cold extremities, and a general depression of all the functions of the body; others, again, show marked signs of neurasthenia, such as loss of muscular tone and tremor of the hands, and complain of sleeplessness, loss of appetite, and vague general pains. Most cases, however, enjoy good health and present no obvious physical changes.

OCULAR SIGNS.

Movements of the Eyes.

The movements of the eyeballs in miners' nystagmus are of a rotatory nature, but are rarely constant in rhythm for any length of time. They are increased when the patient looks up, and upon exertion or excitement, and are diminished and brought to a standstill when the patient looks down. The ease with which the movements can be brought out may be taken as a rough estimate of the severity of the attack. Romiée (89) was the first to call attention to this, and he measures the severity of the attack by noticing at what angle above the horizontal nystagmus may be brought out. He then expresses the result in degrees. For instance, he says nystagmus was present at 10, 30 or more degrees above the horizontal. This is undoubtedly of value, but many more facts have to be taken into consideration before expressing a complete judgment on the case. The so-called lateral or vertical nystagmus is, in my opinion, a rotatory one with a large lateral or

vertical excursion respectively. Both eyes are affected equally, with but few exceptions. I have seen well-marked movement in the stumps of very shrunken and useless eyes.

Case (15). Left eye blind since birth, movements equally marked in the shrunken globe.

Case (17). Penetrating wound of eye with loss of contents, movements equally marked in both eyes.

Case (113). Ruptured globe, result of a fight. Movement equally marked in both eyes.

Case 4 was the only case in which I was satisfied that movement was more marked in one eye than the other. In several cases movement was more marked in the right eye when looking to the extreme right and *vice versa*. The movements may be described as wheel-like, and may be represented diagrammatically in the following manner:—

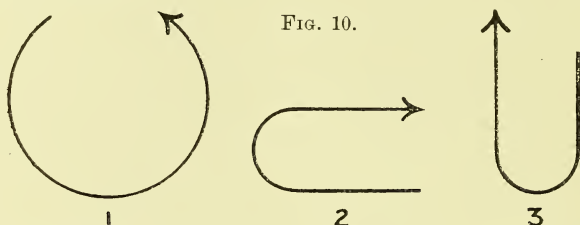


FIG. 10.

The first variety is the commonest, the second is the so-called lateral, and the third, the so-called vertical, is the rarest of the three. In very severe cases the movements persist even when the direction of regard is 20 or even 30 degrees below the horizontal. In 10 of my cases the nystagmus persisted below the horizontal, and in one case even 30 degs. below. In a few cases the eyes are only steady when in the extreme lateral position, and I believe this position is determined through an effort to fix the eyes by making the check ligaments taut.

Snell (106), speaking of the character of the movements, says, "the rotatory are seldom, if ever, absent, but the horizontal and vertical movements may be more or less pronounced." Niden (65), says the movements are rotatory in 72 to 77·5 per cent. In some cases the movements are rotatory in one eye and vertical in the other (65, page 30). Romiée (89) gives the following table:—

	Per cent.
Rotatory	70
Lateral	17
Vertical	11
Oblique	2

Elworthy (41)

	Per cent.
Rotatory	27
Indefinite and mixed	35
Lateral	25
Axial	1
Vertical	12

Rutten (97), lays stress on the pendulum-like nature of the movements, and thinks this character shows the condition to be of cerebral origin.

Rate of Movement.

One hundred to five hundred oscillations a minute. In some cases the movement is so rapid that it is impossible to count, and in these cases I have estimated the rate at 500. The excursion is so fine in some that it is difficult to detect the nystagmus. The rate in general is between 100 and 350. Romiée (89) gives 120 to 500, Snell (106) 60 to 120, and Nieden (65) "80 to 100, a few cases 360" (p. 32).

Range of Movement.

I agree with Romiée (89), who gives the range as 1 mm. to 1 cm. The coarser the movements the slower and more irregular they are; on the other hand, the fine rapid movements are much more constant in rhythm.

Movement of the Eyelids.

These movements are often present, and when marked render the detection of the nystagmus difficult. I have, however, never failed in recent cases in recognising nystagmus from this cause. In my series the sign was present in 136 cases and was marked in 24. The sign has now an additional importance owing to the fact that the Industrial Disease Committee has under consideration the question whether it shall be included in the Schedule of Industrial Diseases as "Clonic spasm of the eyelids apart from nystagmus." This clonic spasm or nictitation of the eyelids has been noted by most observers. I have never seen a case apart from movement of the eyes, but in several cases the sign has been the most persistent of all. I do not think the condition should be included in the list of industrial diseases, for the following reasons:—

(1) I do not think it occurs in miners as a result of their occupation apart from the presence of nystagmus. I have never seen a recent case in which it which it was present, where I have been unable to detect nystagmus.

(2) It is a sign very easily simulated, and I have on several occasions had malingerers trying to pose as genuine nystagmus cases by blinking their eyelids violently.

(3) It is a sign which is found in so many diseased conditions of the ocular apparatus that it possesses no pathognomonic feature.

Tremor of the eyebrows is often associated with nictitation and with tremor of the head. This last sign is frequently present, and can be more easily felt than seen. It can be brought out most readily by flexing the head strongly and asking the patient to look up. It is most persistent, often remaining after the oscillation of the eyes has disappeared, and for this reason I have drawn attention elsewhere (56) to its value as a diagnostic test. I do not think there is any connection between the rhythm of the head movements and those of the eye; they are certainly not antagonistic, as Stassen holds. I regard them rather as a sign of the extension of the disease, as in the most severe cases the movement may spread to the muscles of the shoulder girdle. Tremor of the head was present in 162 cases and was marked in 42.

Slight ptosis, or drooping of the upper lid, is often seen associated with the backward tilt of the head, but there is no marked loss of power in the lid.

The power of fixation is also weakened, and a patient is unable to fix a point held a short distance in front of his eyes; when asked to do so he is at first successful, but the eyes soon roll up under cover of the upper lids and he turns his head away.

Many of my cases show convergence; I have noted it in 14 cases, and probably seen it in more. More than once I have been told that the internal squint has only developed since the onset of nystagmus.

Congestion of the conjunctiva and evidence of ocular strain are often present. One of my cases (458) told me that he was always put to work in the most difficult places when other men had failed—"the strain on the eyes is much worse in these places." Visual acuity is rarely normal even in the absence of movements, and when these are present the vision is very limited. A man may be able to read 6/9 one minute and the next he fails to read 6/12. If the test types are placed at a lower level than the eyes, a better result will be obtained. This fact has been pointed out by Butler in his article in the *British Medical Journal* (10).

CHAPTER II.

Frequency of the Disease and Extent of Incapacity.

FREQUENCY OF THE DISEASE.

THE frequency of the disease has been estimated by various authors from 5 to 24 per cent. of all underground workers. Nieden (65), as a result of an examination of 27,982 miners, came to the conclusion that the frequency was 5 per cent. in all underground workers. He quotes Dr. Höderath (page 44), who found 435 cases in 8,602 men—that is, 5 per cent. He criticises the high figures given by Romiée, and thinks that every little unsteadiness of the eyes must have been counted as nystagmus. Dransart and Famechon (35), give 10 per cent. as the number affected in the North of France.

Romiée and Nuel both estimated the frequency as 20 per cent. in the mines of Belgium. Libert gives the percentage as 23·9 per cent. (54), and Rogers (87), as 17·5 per cent. Court found 34·75 per cent. of all coal-cutters affected, but no other English writer has supplied any figures as to the frequency of the disease. These figures were all obtained by the systematic examination of several thousand workmen, and give a totally erroneous idea of the disease. I believe the figures are all correct, but a much truer estimate of the disease may be obtained by counting only those cases that are compelled to leave off work for some time and those that have trouble with their eyes while at work. In this opinion I am supported in a later communication by Dransart and Famechon (37) in which they say that a distinction must be drawn between the two classes of the disease, the latent and the grave form. These authors say that from 10 to 20 per cent. of all miners are

affected with the latent form, but only .3 per cent. with the grave form. In support of these figures they cite the number of men who attended at the Ophthalmic Institute at Somain, which serves a population of 40,000 miners. In the two years (1908 and 1909) 201 cases attended in all. They quote Nuel as saying that the number of men in the mines of Belgium incapacitated from nystagmus is 0.18 per cent.

The Blue Books on Statistics of Compensation (128-130), give the number of men incapacitated from nystagmus in the United Kingdom, and may be assumed to afford a fair index of the frequency of the disease in this country.

TABLE 3.

	Number of cases of nystagmus.	Percentage to under- ground workers.
1908	460	.057
1909	1,011	.123
1910	1,618	.19
1911	2,519	.29

Compare this last figure .19 per cent., with the 0.18 per cent. given by Nuel.

I reproduce a table from a previous communication (56) :—

TABLE 4.

District.	Cases.	Underground workmen.
A	425	133,000
B	413	56,580
C	27	8,000
D	11	28,000
E	75	12,500
F	2	2,870
G	1	6,855
H	no known cases	5,437

G and H are naked-light districts; F is an anthracite district; B, C, and D are almost entirely safety-light districts, in which a considerable amount of holing is done; A is largely a safety-light district in which holing is the exception.

These figures give the frequency of nystagmus in 1910. I have returns for some of the districts for 1911:—

A	574 cases
G and H	no cases
I (a new district)	225 cases (53,000 men)
(See also tables given on pp. 58-60.)	

My own conclusions may be summed up as follows :—

Cases of nystagmus.	Frequency in a safety lamp pit.
Latent..... }	Up to 25 per cent. of all underground workers. ·05 to 2 per cent. of all underground workers.
Slight manifest ... }	
Ordinary form	

Ten per cent. of the ordinary cases belong to the severe form of the disease.

As a result of a systematic examination of 173 officials, chiefly firemen, employed at 11 separate collieries, I found that 61, or 35·2 per cent., were affected with latent nystagmus. The similarity of these figures to those obtained by Court (34·75 per cent. in coal-cutters) may be pointed out. All the men assured me that they

TABLE 5.—SHOWING THE RESULT OF AN EXAMINATION OF
173 OFFICIALS.

	Nystagmus.	Doubtful.	Free.
Number	61	15	97
Mean age	44·2	37·7	37·3
Mean years of under- ground life.....	28·9	27·9	20·5
Vision—			
6/6—6/9	35	9	76
6/12 or less	26	6	21
Error of refraction	57·3 %.	33·3 %.	28·8 %.
Hypermetropia	19	2	15
Myopia	11	2	7
Astigmatism	5	1	6
Degree of error—			
Less than 1D	24	3	13
1D and over	11	2	15
Colour of hair—			
Fair	23	2	15
Medium	15	5	25
Dark	23	8	57
Colour of eyes—			
Blue and grey	39	8	44
Light and dark brown	22	7	53

were able to do their work without any trouble, and only two acknowledged ever having had trouble with their eyes. To say that 35 per cent. of the men "suffered" from nystagmus would be to give a very wrong impression. The table is interesting as comparing the normal man with the nystagmic, and shows (1) that the older the worker the more likely he is to become affected; (2) the diminution of vision and the greater frequency of error of refraction in the group of nystagmus cases. Even when the normal man had 6/6 vision his answers were in many cases slow and hesitating.

COST OF DISEASE.

In a previous communication (56) I estimated the cost of nystagmus to the country as £100,000 a year. I obtained the result as follows:—

I had exact figures of the amount of compensation paid to 425 cases of nystagmus during the year 1910. Assuming that that figure gave a sufficiently broad basis to work upon, I found the cost of the 1,618 cases certified in 1910 to be £31,853. I extracted the following table from the Blue Books on Statistics of Compensation for the years 1908, 1909, 1910:—

TABLE 6.

Year.	No. of cases.	Increase per cent.	Cost of all industrial diseases in £'s.	Increase per cent.
1908	460	—	13,382	—
1909	1,011	120	26,795	100
1910	1,618	60	42,507	55
1911	2,519	55	68,017	60

It will be seen that the increased cost of charges due to industrial diseases bears a similar rate of increase to that shown by nystagmus. In addition to the compensation charges, the employers lose the profit on the work which should be done by these men, while the workmen lose a sum in wages which may well be double the sum quoted. In many cases the men are not able to earn as much during the twelve months preceding their failure to work. Taking all these factors into consideration, I arrived at the sum of £100,000—a sum which I believe greatly under-estimates the real cost of the disease.

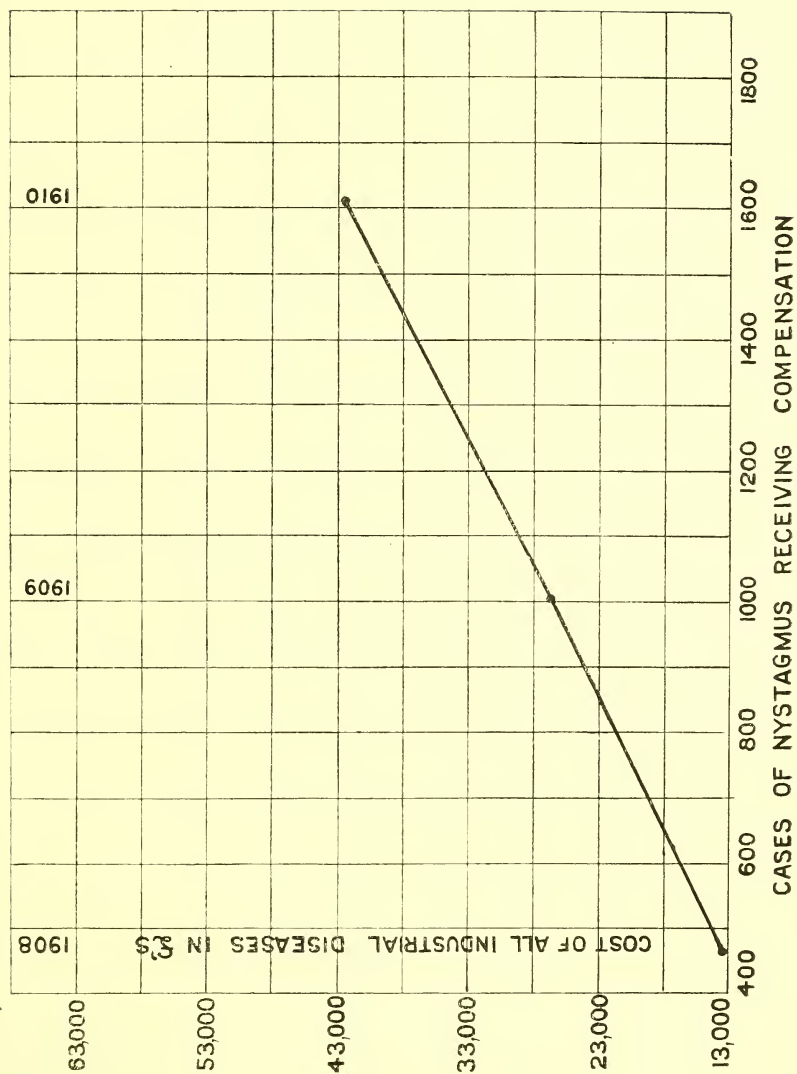


FIG. 11.

INCAPACITY.

Incapacity may be complete in the severe cases and entirely absent in the latent cases. When it is considered that from 10 to 24 per cent. of all underground workers are said to be nystagmic (page 13), and when the number of men who fail to continue their work is found to vary from 0·05 to 2 per cent., it will be seen that in the great majority of cases nystagmus is a trivial disease leading to little or no incapacity. The examination I made of the underground officials showed the presence of nystagmus in 35·2 per cent., and yet only two men said they had had trouble with their eyes. A severe attack of nystagmus is a quite different matter, and there are few diseases which cause greater incapacity. Speaking broadly, severe cases are unable to do any work of a marketable value, cases of ordinary severity can do any work on the surface that does not involve much stooping; while latent or trivial cases can work underground. Idleness is bad for a nystagmic case, and I always advise my patients to work on the surface if they possibly can, because I consider their chances of recovery are increased thereby. The question of surface work is greatly complicated by the policy of the owners and the men; the owners are unwilling to give work to a man who has been in receipt of a large weekly wage, as they have to make his wages up by way of half the difference between his present and past weekly average; while the men are naturally unwilling to accept less than their legal rights. The owners say it pays them better to keep the man idle than to pay a large sum weekly by way of half the difference, but I think this policy is a short-sighted one. If a man is given work before he has drifted into the state of unfitness which always follows idleness, then his chances of recovery are greatly increased, and the probability is that the man will soon return to work underground. I have proved this truth to my own satisfaction. On the other hand, men legally entitled to a large weekly sum representing the half difference would be well advised to compromise in this matter, seeing that the surface work found for them is largely unremunerative to the employer.

One attack of nystagmus should not be taken as a bar to working underground. I have seen many men recover completely and able to earn their usual wages at their old work, and I think it is a great mistake, and one which is not to the interest of the

patient, to lay down the hard-and-fast rule that no man should be allowed to work underground after one attack of nystagmus. The report of the Departmental Committee on Industrial Diseases (132) brings out the fact that the medical opinion that pit work should be entirely relinquished was inconclusive. "The data on which this medical practice is based do not appear to us, from the evidence, to be entirely conclusive, and in some cases, perhaps, the advice appears to have been given as the result of dogmatic statements made on the subject rather than of actual experience.

. . . . In other words, one man may exhibit a very marked oscillation of the eyes and yet suffer little discomfort, and be able and willing to continue at his work; another may show overt symptoms less acute, and yet may claim, and claim truly, that he is incapacitated from his usual employment."

I hold the following views:—Slight cases can soon return to work underground; ordinary cases can return after an interval of surface work of three to twelve months. Although one attack of nystagmus predisposes to another, I think it only fair to allow a man to try to regain his income by working underground if possible. It must be remembered that the collier is a man who enjoys a good income, and also that it is difficult for him to obtain suitable work outside the colliery. The exceptional cases, however, should not return to work underground, and by exceptional cases I mean the following:—Men who have failed several times before; very young lads; old men with commencing cataract; men with high degree of refractive error; and cases where the attack has been marked with exceptional severity with movement persisting below the horizontal. In the case of young lads who develop the disease after a year or so of underground life, it is obvious that they are quite unfitted for the work and they should lose no time in looking for more suitable employment. In the same manner it is difficult to say to what extent nystagmus is due to error of refraction. I have seen cases of nystagmus in men who have never worked underground, and in whom the nystagmus is entirely due to the error present. These men then, quite apart from the presence of nystagmus, should be considered unfit for underground work. I have stated elsewhere the frequency with which a commencing cataract seems to hasten or make manifest the onset of nystagmus. When a man who has recovered is sent underground it is better to employ him at first in the main roads

for a few weeks, and if possible to provide him with an electric lamp. When a man is employed on the surface he should not be given work in a dusty place or in one which requires much stooping.

I have drawn up a table showing the stage of the disease in my own cases. The table presents too dark a view, for the following reasons. My cases are taken from all over the kingdom, and I have only been able to follow up the records of some of them. In many places I saw only the long-standing cases, and the table represents the condition of the men at the time of my first, and in many cases only, examination.

TABLE 7.—INCAPACITY.

Back at old work	160 (latent 118)
On surface work	162 (average time spent on surface to date, 11·8 months)
Idle	277 (average length of idleness to date, 9·8 months)
Dead.....	1

The following table, taken from the returns of five large colliery companies employing over 28,000 men, gives a more correct impression of the disablement produced by the disease. All these cases had been certified.

TABLE 8.—INCAPACITY.

Back at old work	152
Left employ and commuted	9
Surface work (including 12 who had failed to work underground)	105
Still idle*	73

* This does not necessarily mean that the men are unable to work; in most cases it means that the manager does not think it worth while to employ the man on the surface.

In district A (*see* p. 14), there were 425 cases of nystagmus in 1910, 305 were carried forward to 1911; in other words, 110 or 26 per cent. were either cured or settled. I have compiled two tables from the tables given in the Blue Books on Statistics of Compensation. These tables, owing to the fact that all industrial diseases are given together, are not exact, but I think an approximately true average is obtained. The first table was compiled from tables 5 and 6 of the Blue Books mentioned, and the second table from the No. 4 tables.

Industrial Diseases.

TABLE 9.—SHOWING DISABILITY (COMPILED FROM BLUE BOOKS).

Year.	Cases carried forward from previous years.	Fresh cases.	Total.	Cases settled by a lump sum.	Cured.	Per cent. cured.
1908	74	386	460	11	—	—
1909	380	631	1,011	47	69	15·0
1910	662	956	1,618	49	302	28·8
1911	1,144	1,375	2,519	120	354	21·8

The first three columns refer to nystagmus cases alone, but the fourth column "cases settled by a lump sum" is only approximate, as it includes payments for all industrial diseases for mines in which a preliminary weekly payment had been made. As nystagmus is the chief disease for which a lump sum is paid, the figures given will be approximately correct. The figures of the number of cases cured will be low in the proportion that the fourth column is overstated. The figures in the fifth column are obtained as follows:—In 1908 there were 460 cases of nystagmus, but only 380 were carried forward to the next year; 80 cases were either settled or cured. Eleven cases were settled for a lump sum, and if this number is deducted from the previous figure of 80, we are left with 69, or 15 per cent. of the total number of 460 cases.

TABLE 10.—SHOWING LENGTH OF DISABILITY (COMPILED FROM TABLES 4 OF THE BLUE BOOKS).

Period of disablement.	1908	1909.	1910.	1911.
Over 13 weeks and less than 26	95	132	172	223
„ 26 „ „ „ 52	84	110	222	311
„ 1 year „ „ 2	34	214	299	450
„ 2 years „ „ 3	—	28	116	213
„ 3 „ „ „ 4	—	—	18	92
„ 4 „ „ „ 5	—	—	—	15
	213	484	827	1,304

This table also includes all industrial diseases for mines, but nystagmus is almost alone in incapacitating a man for more than 13 weeks; the other diseases from which the miner suffers, such as

beat knee or cellulitis, do not keep him from work for more than 6 or 7 weeks, except in rare cases.

The Mental Factor as a Cause of Incapacity.

The mental factor has no influence in actually producing the disease, except possibly by converting a latent into a manifest attack. The amount of suffering and incapacity produced by the disease depends, however, very largely on the presence or absence of a superadded neurosis. As the Departmental Committee on Industrial Diseases points out, the incapacity cannot be estimated by the physical signs present (*see p. 19*). The ability to work may and does often depend on the mental condition of the patient, and the method in which this mental state acts will be shortly considered.

Neurotic suffering differs from all other forms of suffering, in that it has motive and brings gain to the patient. This gain is not necessarily apparent to the observer or even to the patient himself, but consists largely in the gratification of repressed desires and unconscious longings. For example, a man may have been over-indulged in childhood, and may have always had a great disinclination for work; this disinclination he has been able to overcome in the past, but when the first opportunity offers itself for freedom, he is unable to resist, and allows himself to be persuaded unconsciously that he is unable to do any work. It must be clearly understood that this condition is quite distinct from malingering.

The first and obvious gain is the compensation paid in cases of nystagmus. It is beyond doubt that the inclusion of nystagmus in the schedule of Industrial Diseases for which compensation has to be paid, has greatly increased the number of cases of the disease. Table 6 and Diagram I. show the great increase for the years 1908 to 1910. In Germany, since the introduction of the Workmen's Compensation Act, the number of workmen suffering from neurotic affections has greatly increased—in fact, to such an extent that a new name has been coined for the complaint—"Rentenhysterie," or income-neurosis. Compensation, then, is one gain for the patient, but it is not the only gain, and perhaps not the chief gain. The gratification of repressed desires is the second, and the third motive is brought about by the influence which affections of the eye have on the mental state. Owing to

the intimate manner in which sight has been associated with life and all its pleasures, the eye has a greater influence on the mind than has any other part of the body; and affections of this organ have a far more reaching effect than those of other parts of the body. One of the greatest calamities which can befall a man is to lose his sight, and the mental anguish and distress often seen in cases of cataract will make clear its importance. Some cases of nystagmus are so bad that they fear they will lose their sight—one man told me he had not slept for six weeks, except by snatches, from the mental dread which he experienced. In less marked cases the mind is acted on unconsciously, with a slighter degree of this fear.

The influence of suggestion on the disease was illustrated by a case which I saw in the Midlands. The man had received an injury to his foot, and his doctor noticing that the man had nystagmus, told him so, and told him also that he could get compensation. The man had never had any symptom before, but from that date, on which he was informed by the doctor that he had nystagmus, he suffered from all the classical symptoms of the disease. A latent attack of nystagmus does no harm and causes no incapacity; but tell a man he has nystagmus, and he will soon be found on the idle list. The less a collier knows about nystagmus the better for him, and all discussion of the subject among colliers should be discouraged.

Cases of nystagmus should not be paraded in front of their fellow workmen when compensation is being paid, as the sight of men receiving money week after week cannot fail to have a bad influence on the minds of the other workmen.

THE EFFECT OF NYSTAGMUS ON TESTING FOR GAS.

In the presidential address to the British Medical Association at Sheffield, in 1908, Snell (105) called attention (*B.M.J.* 1908, vol. 2, p. 241), to the great danger which exists from the inability of the nystagmic fireman or collier to detect gas in the usual manner with a safety lamp. In a coalmine, the firemen and colliers make examinations of all the working places regularly, by testing for gas with the flame of the safety lamp turned low. If gas is present, a blue flame, called a cap, will be seen above the small flame of the safety lamp, and the percentage of gas present

can be measured by the size of the flame shown. Snell examined 48 firemen and colliers, all of whom had nystagmus. He found that every man made mistakes, and that several were quite unable to detect any "cap" until the lamp was full of flame. The great importance of this possible source of danger is very obvious, but, strangely enough, as was pointed out in a leading article of the *British Medical Journal* (1912, vol. 1, p. 853), little notice was taken of these observations. In a Report (132) to the Royal Commission on Mines, Mr. E. B. Whatley, one of H.M. inspectors of mines, gives an account of some tests made on 41 firemen, of whom 30 were nystagmic. Those firemen who were affected found it difficult to detect the cap, and recognised the presence of gas by the "drawing" of the flame. A few of the men most affected were unable to see a large cap.

In the beginning of 1912 I made some tests on all the firemen employed in five large collieries. The men were all carefully tested for nystagmus beforehand. The tests were made by placing a safety lamp in a gas chamber at the New Tredegar Rescue Station, and I was assisted in my observations by Mr. Price, the manager of the Elliot collieries, and Mr. Kitto, the superintendent of the station. The men were all allowed to get their sight by remaining in a dark room, and to trim the lamp used to their satisfaction. Many of the men brought their own lamps. The nozzle giving a 3 per cent. mixture was then placed in the regulating tube to the chamber and the gas turned on. The chamber was filled first with pure air, and its contents passed in three minutes from pure air to air containing 3 per cent. of gas. The fireman was asked to tell us immediately he saw a trace of gas as shown by the lamp, and when a 1 per cent. and 2 per cent. cap appeared. A stop watch was used, and when the first indication of gas appeared to one of us it was started, and stopped when the man first saw the change in the flame. It would be tedious to give the results of each examination, but a few examples will be given.

NYSTAGMUS CASES.

- (1) Trace not seen, after 34 seconds he said "trace" when a 1 per cent. cap was visible. When the lamp showed a 2 per cent. cap he was correct.
- (2) Trace and 1 per cent. cap not seen, a 2 per cent. cap he called a trace.
- (3) Trace and 1 per cent. not seen, after 52 seconds he saw a trace when a 2 per cent. cap was present.

The results, however, on the whole, were so good that I tested two bad cases of nystagmus (all the firemen above were latent cases, and the men said they had no trouble with their eyes).

TWO BAD CASES OF NYSTAGMUS (COLLIERS).

(1) This man was practically correct throughout, and saw a 1 per cent. cap as soon as we did.

(2) Twelve seconds late, recognised trace, but under-estimated a large cap.

NORMAL MEN.

(1) Twenty-one seconds late, trace doubtfully seen, 1 per cent. cap called a trace, 2 per cent. cap correct.

(2) Forty-five seconds late, 2 per cent. cap called a trace.

(3) Four seconds late, otherwise correct.

The results shown in the table were very surprising to me, as I had expected the nystagmus cases would have had much more trouble than is shown. Nystagmus does make the detection of the cap more difficult, and the great danger is that a careless fireman, not seeing a cap at once, would overlook a collection of gas. The normal firemen made no bad mistakes, although several were slow and failed to detect the first appearance of the cap. The table shows the number of men who failed at the different stages of the test. Taking the 1 per cent. cap, four of the normal men failed to see it, and nine said that only a trace was present—that is, they under-estimated the amount of gas present.

Examination for Firedamp.

TABLE 11.

	Number tested	Correct.	Fairly correct.	Trace.		Cap shown.					
				Slow.	Failed.	1 %		2 %		3 %	
						Failed	Under-estimated.	Failed.	Under-estimated.		
Normal.....	49	28	8	17	14	4	9	0	14	Cap seen in all cases but frequently under-estimated.	
Nystagmic cases.....	41	4	7	21	19	10	13	6	12		

CHAPTER III.

Historical Account of the Disease and Theories of its Causation.

THE first case was described by Decondé (25, 26) in 1861 in a paper dealing with nystagmus generally (*Arch. belg. de Méd.*, 27, p. 337, and *Ann. d'Ocul.*, 1861). Snell in his book (p. 15) says that a Dr. Gillet, of Sheffield, recognised the disease in or about 1854. Nieden (65) says that Peppmuller described cases in the period 1860-63. C. Bell Taylor published a paper in 1874 on "Miners' Nystagmus, a New Disease" (*Lancet*, 1875, vol. 1, p. 821). In this paper he considered the disease analogous to writers' cramp, and thought the condition due to overburdening of the muscles and the sustained effort to see in a deficient light. Later (112) (*B.M.J.*, 1887, vol. 2, p. 483) he says "there is no central lesion, the affection is a pure myopathy."

Nieden says that von Gräfe (47) in 1873 and he himself in 1874 described cases independently. In his book, *Der Nystagmus der Bergleute*, published in 1884, Nieden summarises his views as follows (p. 120-122):—

Nystagmus is almost exclusively found in those workers who are compelled to work in a constrained position with the visual regard directed upwards. The resulting overburdening of the elevator muscles, already unfitted by nature for strenuous work, produces the nystagmus. Men working in somewhat similar positions, such as ceiling painters, house painters, &c., "never or only in very few cases suffer." The conditions of illumination must be blamed when, through lack of the necessary light which the safety light gives compared with that of the open light, the overstraining of the elevators produces the disease in the hewers. The condition resembles the tremor found in old age, the result of muscular fatigue. The causes are, in the first place, lack of light; secondly, defects of vision; thirdly, insufficiency of the interni

with a corresponding weakness of the associated movements of the eyes; and fourthly, the general ill-effects of the work performed (p. 140).

Dransart (28) in 1877 (*Annales d'Oculist*, 1877, 11 série, t. 8) published his first paper, in which he says nystagmus is due to a myopathy of the elevator muscles of the eye. In this paper, after calling attention to the work of Nieden, Gräfe and Nuel (1874), he quotes Arlt (1867). In this reference Arlt attributes the movements of the eyes in nystagmus to an attempt to bring a fresh part of the retina to bear on the same point in the interest of vision. Later (29) (*Annales d'Oculist*, 1882, 12 série, t. 7, p. 150), Dransart says that a large percentage of the sufferers are anæmic, and states that errors of refraction have nothing to do with nystagmus. In a letter to the *British Medical Journal* (August 8, 1891) he expresses agreement with Snell as to the influence of position "as the first prime cause in the production of the disease." He returns to the subject in a communication with Famechon (35), in which (*Bull. de l'Acad. Roy. de Belg.*, 4 série, 22, p. 424) he says that the condition is due to muscular fatigue, aggravated by deficient light, but chiefly due to the position of visual regard—the result of working in small seams. He lays great stress on condition of health and influence of accident, especially injuries to the cornea, and quotes Razemon (82) and Thevenon (113) in support of this last contention. In a later communication with Famechon (37) he lays the greatest stress on the importance of fatigue as the essential cause.

In 1875, Snell (99) drew attention (*Lancet*, 1874, vol. 2, 981) to the position assumed by the holer at his work, and laid stress on its importance as an etiological factor in the production of the disease. In his papers in the *Lancet*, 1882, vol. 2, p. 103; *Trans. Ophth. Soc.*, 1884; *B.M.J.*, 1891, vol. 2, p. 61; *B.M.J.*, 1892, vol. 2, p. 835; and especially in his book on *Miners' Nystagmus*, in 1892, he states definitely that in his opinion the disease is caused by fatigue of the elevator muscles of the eyes, and that it is similar to writers' cramp. He sums up (p. 97) as follows:—"It (nystagmus) is occasioned by fatigue of the superior rectus, inferior oblique, and internal and external recti muscles, induced as a consequence of the miner's work in the pit necessitating an upward and more or less oblique gaze. It occurs irrespective of the mode of illumination." In the *Trans. Ophth. Soc.*, 1891, p. 102,

he published his famous case of nystagmus in a compositor. Here nystagmus appeared for a short time in a young lad who, according to the description given, used to pick out the type arranged in a box above him, by elevating his eyes only, keeping his head level. Snell's main contentions are these:—That the disease only attacks men who are compelled through the nature of their work to direct their gaze upwards, *i.e.*, hewers and deputies (97 per cent.); and that the disease is most readily brought out by asking the patient to look up. “The position of the miner at his work is therefore the prime and essential cause of miners' nystagmus” (p. 97).

Court, in a report to the Derbyshire Miners' Association in 1891 (20), and in the *B.M.J.*, 1892, vol. 2, p. 834 (22), lays the greatest stress on the importance of illumination. He says that where torches, candle power $2\frac{1}{2}$, are used there is no nystagmus, and that as the result of a systematic examination of 1,169 colliers he found—

Of 597 men who used safety lamps there were 207 cases of nystagmus
572 „ „ „ naked lights „ „ 32 „ „

Of these 32 cases in naked light pits, he found that 29 had worked previously with safety lamps. He calls attention to the shadows cast by the bonnet and oil reservoir of the safety lamp, and to the fact that the dirty lamp only gives three-quarters of the light of a clean one, the light of the candle remaining constant all day.

Jeaffreson (*B.M.J.*, 1887, vol 2, p. 109) says that the disease is a general one, with nystagmus as one of a group of symptoms, and suggests the name miners' neurosis. He thinks that position alone is not sufficient to produce the disease, but that when helped by a disassociation of movements normally combined nystagmus results. In walking along underground a man may be compelled to flex his head strongly and yet keep his eyes directed upwards to avoid striking the roof. Normally head and eyes should go up together. He states that nystagmus is not found in house painters, who have to look upwards continually, and gives an interesting account of Michael Angelo, who, after painting the frescoes in a church, had to write with the paper held above his head.

Romiée made his first communication in 1878. In 1892 (89) he published a paper in the *Bull. de l'Acad. de Méd. de Belg.*, 1892, 4 série, 6, p. 299, in which he says that excessive accommodation

for a long time in a bad light is the chief factor in the production of nystagmus. Cases are rarely emmetropic; most are hypermetropic, often to a marked degree. In the *Bull. de la Soc. Belge d'Ophth.*, No. 25, p. 76, he states that the safety lamp was recommended for use in the mines of Belgium in 1851, while in 1876 the use of the Mueseler lamp was insisted on by the Government, and it was in the next two years that he noticed an increase in the number of nystagmus cases. He says our forefathers were at least as good observers as we are, and that if the disease had existed before the introduction of the safety lamp they would have discovered it. He quotes figures which show that with the improvement of the lamps used there is a great diminution in the percentage of nystagmus. After the introduction of the powerful Wolf lamp the cases of nystagmus in one pit in 1908 fell 50 per cent. below the figures for the same pit in 1891 (p. 84). He quotes (p. 84) Lewuillon of Mons:—

Percentage of cases with the Mueseler lamp	38
„ „ „ electric lamp	19

He ends his communication (p. 85) in the following words:—

L'éclairage insuffisant est la cause unique de la production du nystagmus des houilleurs.”

An interesting discussion followed the reading of Romiée's paper. Coppez (p. 85) did not agree as regards the importance of accommodation, while Rutten (p. 87) did not agree as to the prime importance of light. The latter thought the disease was of nervous origin, and that the remedy lay in the diminution of the hours of work. “Fatigue is the cause of nystagmus” (p. 98). In another place (97) he brings forward the current German idea that the disease is the result of movements of the eye to counteract the inclined position in which the head is held.

Delantsheere says that repairers of locomotives who work in a constrained position with insufficient light never get nystagmus (p. 108).

M. Peeters, of Curtrai, said he had never seen any cases in men employed in the photographic works of his district. These men worked in a red light for ten hours a day with one and a-half hours interval at mid-day (p. 108).

Nuel (p. 100) maintains that darkness of the mine with prolonged elevation of regard are the two chief factors in the production of nystagmus, and that one factor alone is not

sufficient (p. 106). He ends his address by saying that coal is a black and crystalline substance, two qualities of great importance in the production of nystagmus. He quotes a case of nystagmus in a polisher of black marble who always worked looking upwards. In a previous communication (*Bull. Acad. Roy. de Méd. de Belg.*, 1907, 4 série, 21, p. 489) he lays great stress on elevation of the eyes as the absolutely predominating feature of the disease.

Rutten (*Le Concours Medical*, No. 48, 1911, p. 1087) holds that the movements of the eyes in miners' nystagmus are involuntary, inimitable and rhythmic, and that they are not choreic. He goes on to say that the movements resemble the other nystagmic tremors, and are due to the contraction of the antagonistic muscles when these should be relaxed; that the abnormal position assumed by the miner is the cause of the disease, elevation of the eyes alone not being sufficient. He maintains that when the head is inclined the eyes move in an opposite direction to counteract the effect of this inclination. This is the theory to which the name "Gegenrollung" has been given by the Germans. According to Rutten, nystagmus is due to the constant alteration of the position of the head necessary in small seams:—"Il doit exécuter constamment des mouvements de la tête, tantôt l'inclinant sur le côté, tantôt la rejetant en arrière, ou bien il doit combiner esemble ces deux mouvements." He makes the following conclusions with regard to the theory of Gegenrollung:—

- (1) It is the only theory which accounts for all the facts.
- (2) It involves all the muscles of the eye, while the theory of elevation only affects the elevator muscles and the inferior oblique.
- (3) Gegenrollung is involuntary and of nervous origin.
- (4) The attitude assumed instinctively and unconsciously by the miner (head back, &c.) is explained by this theory.
- (5) The miners who sit on a buffett* do not get the disease, because there is no inclination of the body and no Gegenrollung.
- (6) Horses do not suffer from the disease, because there is no Gegenrollung.
- (7) The pendulum-like form of tracing shown by the nystagmus of miners is alone enough to show a cerebral origin.
- (8) Alteration in the position of the body brings out nystagmus.

His final conclusion is that the disease is a neurosis.

Mlle. Ioteyko (*La Revue Psychologique*, fasc 2, 1909) thinks that

* Return from colliery 17: "The miners sit on a buffett at their work. Nystagmus '8 per cent."

the study of the ties and occupational cramps throws a clear light on the pathology of miners' nystagmus. She agrees with Dr. Rutten as to the great importance of fatigue in the production of the disease, and thinks the mental attitude must also be taken into consideration. She regards the disease as a neurosis, and thinks the attitude at work, the unbreathable air of the mines (l'air irrespirable des mines) and the complete absence of sunlight form a triad of evil conditions which bring about the disease. The absorption of gases from the coal also has an effect.

J. Tatham Thompson, in the *Trans. Ophth. Soc.*, vol. 11, p. 87, says that the disease is rare in naked light pits. Nystagmus is rarely found in the emmetropic eye. The factors are insufficient light, muscular strain, deficient accommodative power, ametropia, dust and unhealthy air. He brings forward the same views in the *Lancet* (116), 1891, vol 1, p. 311, and in the *British Medical Journal*, 1892, vol 2, p. 839.

A. Christie Reid (Brain 29, part 3, 1906) in a most interesting paper, puts forward his equilibration disturbance hypothesis. He says that in the miner we have imperfect fixation, due to a dim light and frequent disturbance of position. He thinks that the more or less rhythmical series of movements performed in swinging the mandril, the eyes remaining fixed, is an important factor in the production of the disease. Fatigue is not sufficient, as all the muscles of the eyeball are involved, and there is no hyperphoria as you would expect if the elevator muscles were alone affected.

Harrison Butler (*Ophthalmoscope*, vol. 8, Aug. 1) gives an interesting summary of the subject. He points out that a fatigue curve of a muscle shows a tetanic and not a clonic form. He lays stress on imperfect fixation and on the crystalline surface of freshly-cut coal causing a struggle between the two eyes and so impairing binocular vision.

Stassen (*Annales de la Soc. Méd. Chir. de Liège*, September 1909, p. 290) gives an account of an examination of 3,385 workmen, in whom he found 737 cases of nystagmus. Nystagmus was easier to obtain in men who had just finished their day's work. He reviews the rival hypotheses of Snell and Romiée, and decides that neither is sufficient. He says that nystagmus is almost as common in naked light pits as in safety lamp pits, but acknowledges that the disease is less marked in the former class of pit. He mentions the views of Trombetta and Pechdo. Trombetta (120) attributes the disease

to the irritation of the labyrinth (inner ear) produced by the rapid and frequent changes in the atmospheric pressure, and to the incessant blows of the pick and the shot-firing which takes place in the mine. Pechdo (77) says the disease is due to absorption of the gases of the coal. Weekers (*ibid.*, p. 303) thinks that failure of adaptation to the varying light is at the root of the mischief.

Peters (*Archives of Ophth.*, vol. 36, 1907, p. 667) brings forward another view of the pathology of the disease in a paper entitled "Is Nystagmus of Labyrinthine Origin?" He lays great stress on the backward tilt of the head which is so often found in nystagmus, and asks whether this position is a primary one or one designed to overcome the upward movement of the eyeballs. His view is opposed by Ewald and Ach (*ibid.*), who say that, although the labyrinth has an influence on muscular tone, nystagmus does not follow when the head is placed in other abnormal positions, such as in torticollis.

Elworthy (*B.M.J.*, 7 Nov., 1910) thinks that absence of colour is the chief factor, leading, as it does, to exhaustion of the eyes from working in general blackness without any colour relief. Co-ordination is lost and spasm sets in.

Arthur (*B.M.J.*, 1910, vol. 1, p. 967) thinks the disease less frequent than formerly, and the cause to be due to the intermittent impaction of the waves of light on the retina. T. Ritchie Rodger (*B.M.J.*, vol. 1, 1910, p. 929) relates a bad case following an attack of influenza. J. L. Thomas, in an interesting letter (*B.M.J.*, 1910, vol. 1, 1085), says that in 17 years' practice in a district of 1,000 miners equally divided between naked and safety lamp pits, he found nystagmus almost absent in the former pits, but common, especially after influenza and in alcoholics, in the safety lamp men. Carruthers (*B.M.J.*, 1910, March 6) suggests error of refraction as a cause. Ashford (*B.M.J.*, vol. 1, 1910, p. 901) says the age of most patients is under forty. Tomlin (*Med. Chron.*, 1911, October) gives an interesting *résumé* of the subject, and in his summary states that "miners' nystagmus differs in no wise from the other varieties of nystagmus." He attributes the disease to a failure of the central co-ordinating mechanism in the mid brain, brought about by the low illumination, the rhythmical use of the pick, and the crystalline fracture of the coal.

Edridge-Green (*B.M.J.*, vol. 1, p. 1127, 1912) puts forward the view that the nystagmic movements are an attempt to bring the

fovea into the visual axis. He says the fovea is blind when there is no visual purple in it, and that diffusion into the fovea is caused either by light falling on an adjacent portion of the retina containing rods or by movement of the eye. "In the conditions usually obtaining in a mine, sufficient light does not fall upon adjacent portions of the retina, and so the eye is in continual movement." Repetition of this movement produces nystagmus.

Norman (66) calls attention to the personal factor of the disease, and finding that 90 per cent. of 200 cases examined had error of refraction, thinks that this is the determining factor—the last straw, so to speak, which breaks down the fixation centre and so brings about the onset of the disease. He thinks the disease is a perversion of the function of central fixation, due to the conditions under which the coalminer works, but determined by a personal factor which, in the majority of instances, is an error of refraction. The three factors which bring about the disease are

- (1) Defective illumination in the pits.
- (2) Cramped position at work.
- (3) Refractive errors on the part of the men.

On July 19, 1912, a discussion on "Miners' Nystagmus (Neurosis)" took place at one of the sessions of the Oxford Ophthalmological Congress. Several gentlemen took part, and a brief description of the meeting will be given. Mr. Harrison Butler, in introducing the subject, called attention to the importance of accident in the causation of the disease. He criticised Snell's cases of nystagmus in men other than miners, and did not consider them true cases of nystagmus. Nystagmus was not essential for diagnosis, and he thought there was a distinct neurotic type of the disease. He showed two cases in whom he had been unable to obtain any movement of the eyes.* Night blindness was present in 60 per cent. of his cases, and error of refraction in 45 per cent. He considered the theory of cramped position to be overdone, and said that the men always assumed the most comfortable position possible. Bad light was a very important factor in the disease, and he had only seen one case from a candle mine. Deficient light, however, was not the sole cause of the disease, and the possibility of absorption of the volatile hydrocarbons of the coal, leading to a chronic poisoning, should

* Nystagmus was seen in one of these cases by several of the members present.

not be overlooked. With regard to the greater ease with which nystagmus could be obtained in the elevated position of the eyes, he called attention to the fact that even in disseminated sclerosis nystagmus was often only obtained in the extreme lateral position of the eyes. He considered the disease to be a neurosis peculiar to coalminers.

Dr. Court repeated his well-known observations on the relative frequency of the disease in open and safety light pits (*see* p. 28). He thought there was a pre-disposition to the disease, but did not agree that error of refraction had any influence.

Dr. Elworthy, whose contribution was far and away the most original produced at the congress, brought forward a very elaborate series of measurements in support of his colour relief hypothesis. It is necessary to discuss his views fully. Dr. Elworthy, who takes it for granted that deficient illumination is the factor producing the disease, says that light, colour, and surface brightness are the three chief factors to be considered. He advances the view that visual acuity is almost as good with half the light and twice the colour as with half the colour and twice the light. "It seems to me that the thing of importance is the amount of light that is reflected back from the surface into the collier's eyes rather than the amount of light thrown on that surface." Taking the three factors, light, colour, and surface brightness separately, he combines the results to obtain what he calls the "chromophotic index" of the mine. The light factor he obtains by measuring at the working face the candle-power of the illuminant used. The colour factor is measured by comparing the surroundings with specially prepared cards, and the result expressed in colour units which represent the proportion of white present. The surface brightness is obtained by measuring the amount of light reflected from the coal face at a "mean point" between two working places, the lamps being left in the position in which they would be placed by the collier. Multiply these three factors together and you get the "chromophotic index." Nystagmus is common in mines with a low index, and rare or absent in mines with a high index. The great fallacy is that the measurements were apparently limited to a set of three single and separate observations in one working place of one district of each mine. Eight mines in all were examined, so his conclusion is built up on the complicated inter-relationship of 24 single observations.

Some of his results will be given:—

Mine.	Lights used and C.P. at face	Colour relief.	Surface brightness at "mean" place.	Lights apart.	Chromo- photie index.	Nystagnus per cent.
No. 1 Marine	Marsaut .19	2.55	.00055	Ft. 18	26	.89
No. 1 Waunlwyd	„ .44*	2.78	.0033*	7	403	.80
Ebbw Vale level	Candles 1.05 (wax)	10.65	.0042	12½	4,701	Nil
Graig Fawr level	Candles .62 (tallow)	2.4	.0028	4½	416	.106
Dolcoath Mine ...	Candles .92 (tallow)	14.0	.049	4½	63,112	Nil

* Observations not reliable, as wire connecting lumeter to the accumulator was found to have been almost cut through at terminal.

The first measurements, those of the candle-power of the illuminant used, are undoubtedly correct for the single lamp or candle used, but it would be very inaccurate to estimate the average candle-power of the lamps at one colliery from one reading of one lamp. The measurements of colour relief are not convincing. I quite fail to see why two coal levels in the same district should give such discordant results as those given by the Ebbw Vale and Craig Fawr levels. It is, however, with the value of the surface brightness measurements that I do not agree. The first measurement of surface brightness given is .00055 foot-candles. In other words, the reading is supposed to be correct to 1/100,000 part of a foot-candle! Such accuracy cannot be obtained by experts even under the most favourable conditions, and is impossible in the coalmine. The illumination of a place depends on the distance of the lamps from the coal and not on the distance between the lamps of two colliers working in adjoining stalls. The men move their lamps from time to time, and in Dr. Elworthy's paper the distance varied from 3 to 24 feet, or, in other words, the illumination varied from 1 to 64 (as the square of 3 to the square of 24; 9 to 576 or 1 to 64). Dr. Elworthy proceeds to speak of the effect of whitewashing the roof; this had the effect of increasing the "chromophotic index" from 26 to 266 in one pit, and from 403 to 2,522 in another. He also says that the white-washed roof retained 50 per cent. of its brightness at the end of a

fortnight. It seems to me that Dr. Elworthy has taken a round-about way of saying that nystagmus varies with the illumination present, and with this conclusion I completely agree.

Dr. Tomlin said that in his district there were two adjacent coalmines, one a candle pit and the other a safety lamp pit, and that nystagmus was more frequent in the candle pit. This was explained by the fact that the managers of the neighbouring safety lamp pits unloaded all their nystagmus cases on to the candle pit. He said that two of his cases were unable to detect a 5 per cent. gas cap.

Mr. Coulter, of Newport, Mr. Cridland, of Wolverhampton, Mr. Ridley, of Leicester, and Mr. Risely, of Sheffield, all said that deficient light was the chief factor of the disease. Mr. Cridland thought that the quality of the light might have some effect, and suggested a spectroscopic examination of the various illuminants. He found that in three cases out of 13 examined the field of vision was markedly diminished.

Mr. J. Jamieson Evans, of Birmingham, thought that there was a neurotic type of the disease. Several of his cases had occurred in families.

Mr. Folker, of Hanley, said that 75 per cent. of his cases had error of refraction, and that the greater the error the greater the amount of nystagmus present. Accurate correction by suitable glasses greatly improves the patient's condition. Mr. McMurray, of Stoke, thought that movement of the eyes was present in all cases of nystagmus. He thought there was no night blindness. Dr. Norman, of Sunderland, repeated the views which I have already summarised on p. 33. My own contribution has been incorporated in the substance of this book. The Congress passed two resolutions unanimously:—

(1) That the chief factor in the disease was the deficient light present in the mine.

(2) That the Government be asked to appoint a Departmental Committee to deal with the question.

CHAPTER IV.

Conditions Determining the Occurrence of the Disease.

SEASONAL PREVALENCE OF THE DISEASE.

UNFORTUNATELY I am not able in all cases to give the month in which my patients ceased work, for the reason that many were long-standing cases who had forgotten the date of their failure. Dividing the year up into quarters, I obtain the following figures :—

	Cases of nystagmus.
January-March	95
April-June	83
July-September.....	52
October-December	93

Dransart and Famechon (37) give the figures in their cases for the years 1908 and 1909, as 67, 36, 35 and 63 for the four quarters of the year. Adding these two sets of figures together :—

January-March	162 cases or 31·1 per cent.
April-June	119 „ 22·7 „
July-September	87 „ 16·6 „
October-December ...	156 „ 29·7 „

The third quarter, which reaps the benefit of the sunlight of its own and the three previous months, has the smallest number of cases. Dransart is content to quote the fact and offers no explanation. My explanation is that nystagmus is more common in the months of winter because of the absence of sunlight, which alone is able to stimulate the retina to the proper extent. Cure is more readily brought about in summer than in winter, as Elworthy has pointed out (41).

AGE.

It may be taken as a general rule that the longer a man works in the pit the more likely he is to get nystagmus. The older the colliery the greater the number of cases of nystagmus on its books, is a statement which is generally true. Nieden (65) gives the following table :—

Age.	Per cent. of nystagmus.
15 to 25	1·4
25 „ 35	23·4
35 „ 45	43·2
45 „ 55	25·3
55 „ 65	6·65

Libert (54) as a result of an analysis of 262 cases, gives the following :—

Age.	Cases of nystagmus.
12 to 20	4
20 „ 25	5
25 „ 30	17
30 „ 35	39
35 „ 40	59
40 „ 45	45
45 „ 50	39
50 „ 60	45
Over 60	9

The mean age of my series was 39·33 years, and the mean years of underground life were 25·94. Elworthy (41) gives the corresponding figures in his series as 35·5 and 21·25 years. The tables and diagram will show the number of my cases to each quinquennial period :—

TABLE 12.

Age at onset.	
15 to 20	11
20 „ 25	36
25 „ 30	59
30 „ 35	80
35 „ 40	119
40 „ 45	108
45 „ 50	69
50 „ 55	53
55 „ 60	39
Over 60	26
	<hr/> 600

TABLE 13.

Years of under- ground life.	
1 to 5	14
5 „ 10	32
10 „ 15	71
15 „ 20	90
20 „ 25	116
25 „ 30	83
30 „ 35	71
35 „ 40	46
40 „ 45	51
45 „ 50	21
Over 50	5
	<hr/> 600

These tables are also shown in a diagrammatic form.

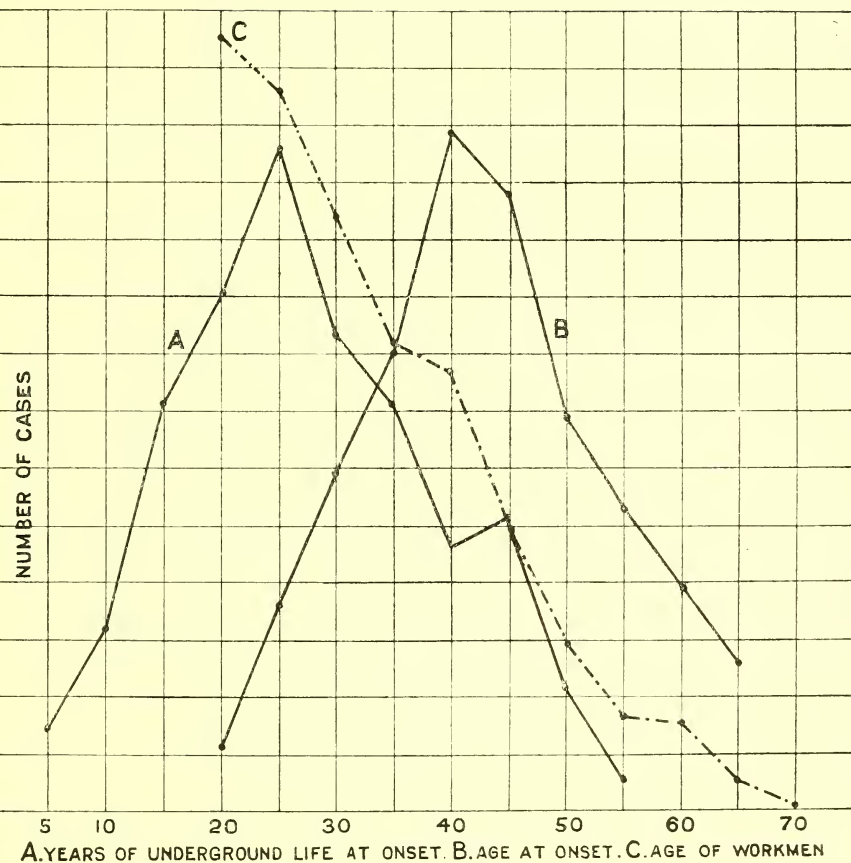


FIG. 12.

B and A represent Tables 12 and 13 respectively in graphical form. C is a comparison graph obtained by tabulating the numbers of underground men (3,818), employed in four steam coal collieries, under the same quinquennial periods. In order to bring graph C to the same scale as A and B, the numbers obtained were all divided by six. To obtain the exact figures of the number of men at the different ages, the figures shown in this graph C must be multiplied by six.

My youngest patient, case (323), was 15, and 47 of my cases developed the disease before the age of 25. The shortest period of underground life was eight months, in case (19). Mr. Binns, of Derby, kindly sent me notes of a case that developed the disease after working a period of $19\frac{1}{2}$ weeks underground. The man was 32 years of age and worked as a filler in a safety lamp pit.

Cases in Young Men.

(19) A collier age 22 who had only worked underground for eight months. Safety lamp pit always. On September 20 he strained his back while at work and was idle for three weeks. At the end of this time, October 11, he noticed that his eyes were affected. The symptoms came on suddenly at night and were quite marked. He was a fair blue-eyed man with no error of refraction. After a few weeks' idleness he accepted a small lump sum and gave up pit work entirely. I met him two years afterwards quite recovered.

(35) Collier's boy, age 20, underground $2\frac{1}{2}$ years. Fair, blue-eyed, with hypermetropic astigmatism.

(91) Collier's boy, age 17, underground $4\frac{1}{2}$ years. V. 6/6. Dark.

(132) A filler, age 19. Has never cut coal, his duty is to place in the tram the coal cut by the collier. Onset three years before failure. V. 2/12. I was unable to do retinoscopy. Vision not improved by glasses.

(133) Filler, never worked on coal. Age 20, underground 6 years. V. 6/18. Nearly 6/6, with $-2.75D$.

(157) Boy age 17, underground $3\frac{1}{2}$ years. A putter, his duty is to drive the horse to the stalls and out. The lad has a marked convergent squint and complains that he sees double at times. Slight hypermetropic astigmatism. Nystagmus only seen with difficulty.

(253). Collier, age 22, underground 8 years. Marked nystagmus even in horizontal position. Myopic astigmatism.

(258) Collier, age 24, underground 11 years. Symptoms followed immediately after a slight blow on the eye. Myopic astigmatism.

(265) Haulage man, age 24, underground 7 years. Marked myopic astigmatism

(294) Collier boy, age 18, underground 2 years. Marked myopic astigmatism.

(310) Collier boy, age 18, underground 5 years. Right eye lost through an accident two years before failure. "I have had trouble with my eye ever since my accident."

(325) Collier boy, age 15 years, underground 2 years. Irregular movements present, but no definite nystagmus when I saw him. He was certified. Vision equal to 3/12. I was unable to do retinoscopy. This lad had marked night blindness. "I go to bed when the lights are lit."

(488) Boy, age 16, underground 2 years. The first six months he spent on the coal, the last 18 driving a small haulage engine. He complained of symptoms at the end of 12 months' underground life. Well-marked nystagmus and slight hypermetropic astigmatism.

All these cases come from safety light pits.

OCCUPATION.

It is generally acknowledged that men who work at the coal face are more likely to be attacked than any other class of workmen, and some authors go so far as to say that the disease is practically confined to coal hewers. Dransart gives 97 per cent. coal hewers, Snell 96 per cent., Thompson and Nieden chiefly coal getters, and Jeaffreson "confined to coal hewers practically without exception." Roger, Libert, Stassen and Romiée, all say that other workers may be affected. Romiée (89) found the various grades attacked in the following proportion:—

Hewers	20 to 65 per cent. of men examined.
Timbermen	7 to 30 " "
Hauliers	3 " "

Stassen found the disease in hauliers, and says that the best workmen are those attacked. Elworthy says: "The only class of workers in coalmines that seem immune is the ostlers, and that is because the stables are whitewashed." The table gives the occupation of my cases, and in addition the percentages of the

TABLE 14.—OCCUPATION.

Occupation.	No. of cases.	Per cent.	Per cent. of workmen in steam coal pit.	Relative percentage.
Colliers	428	81·63	60	1·36
Collier lads and fillers.....	12			
Timbermen and repairers	41	7·6	8·7	·87
Hauliers and haulagemen	39	7·23	14·6	·5
Labourers	6	1·11	1·8	·6
Rippers	5	·93	2	·46
Under-officials	3	·55	1·9	·29
Contractors and hard ground men	2	·37	7·5	·05
Hitcher	1			
Engine driver	1		various	
Ostler*	1		3·5	

* This man had been a haulier.

various grades employed in a steam coal colliery employing 2,500 men.

The occupation of 539 cases is given, the remaining cases were under-officials who had been specially examined for nystagmus, so I felt it would be quite unfair to include them in the table. The other latent cases, 54 in number, were not examined for nystagmus, but the presence of the disease was obvious.

Every class of underground worker is affected, but the men who work at the coal face suffer the most. It is interesting to note that the first two classes contain 89·2 per cent. of the total number of cases. These men are the most skilled workmen in the pit and have to use their eyes more than the others. The collier wins his coal in one of three ways :—

- (1) By holing.
- (2) By taking advantage of the cleavage lines of the coal.
- (3) By the use of coal-cutters.

HOLING.

According to Snell, Dransart and Nieden, the operation of holing necessitates an upward direction of vision, and throws such a strain on the elevator muscles of the eye that a myopathy results with nystagmus as a consequence. It is necessary to describe the operation in detail so that a clear understanding of the process may be obtained. Holing consists in undercutting the lower portion of the coal or the underlying clod to a distance varying from 18 in. to 6 ft. The method of holing varies with the seam; in the thin house coal seams of South Wales the collier kneels at his work, and holding his body a little obliquely, keeps his head against the roof. The direction of regard in these cases is downwards. In the thinner seams and especially in the Forest of Dean and Somersetshire, the collier has to assume a semi- or complete reclining position. In the first instance, he lies with one leg drawn up under him, and the lower shoulder just clear of the ground. In the complete position he lies on the under shoulder. In the Midlands, where the coal is often 6 ft. thick, the collier holes to a distance of 5 to 6 feet, dragging his body completely underneath the ledge of coal. He generally has to lie completely on the side, although even in this district I have seen them use the semi-reclining position. The vertical amount of coal removed

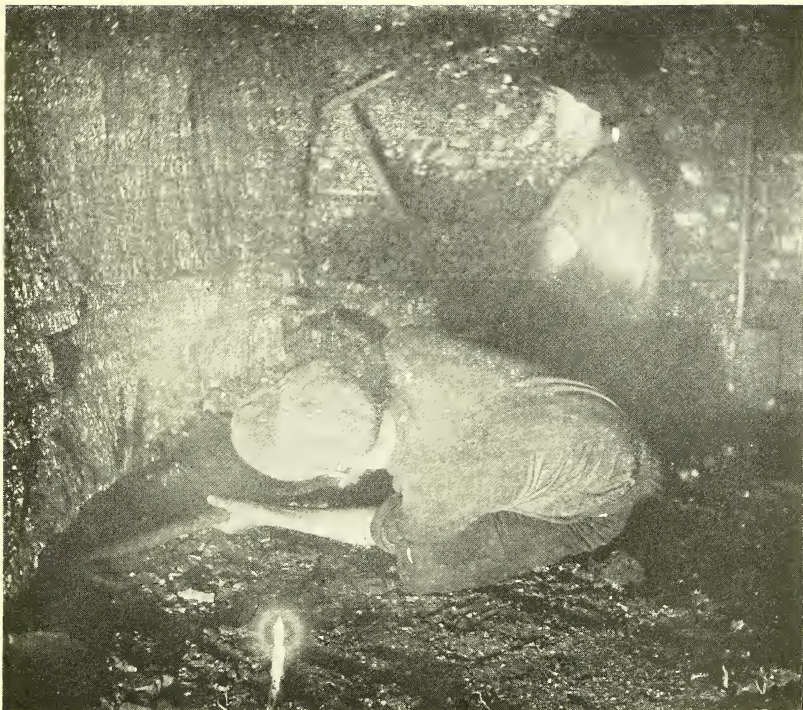


FIG. 13.—METHOD OF WINNING COAL. (I.)

The first collier is holing under the coal and is in the semi-reclining position with his lower shoulder resting on the drawn-up knee. His direction of vision is straight forward. In this instance the holing was only carried out to a distance of 12 in. The second collier is cutting the coal free at the rib. In this manner a narrow cleft is cut into the coal, throughout the thickness of the seam, for a distance corresponding to the amount of holing done.

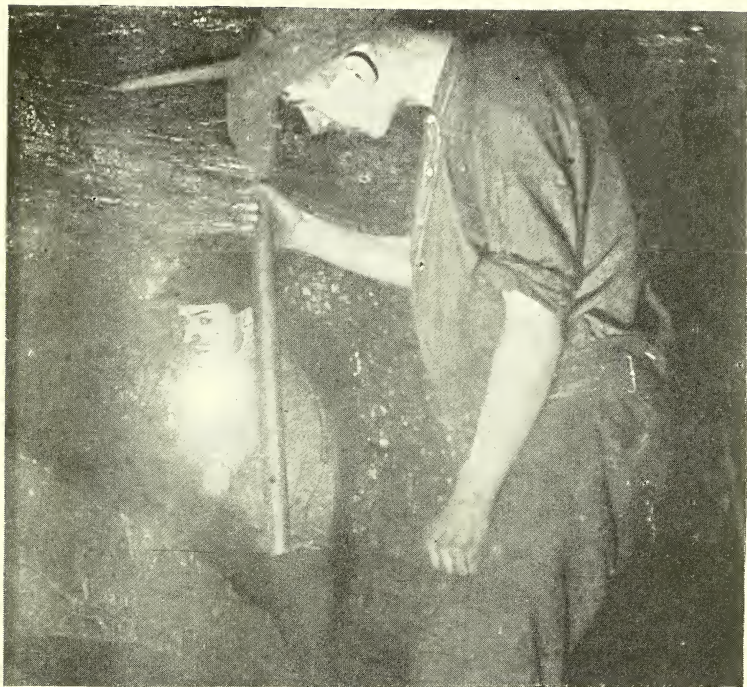


FIG. 14.—METHOD OF WINNING COAL. (II.)

This photograph was taken after the undercut coal had been drawn. The loose coal is seen in the foreground, and the amount of holing is shown by its thickness. The first collier is engaged in sounding the roof with his pick.



FIG. 15.—PHOTOGRAPH OF A COLLIER HOLING IN THE BOTTOM OF THE COAL.

The direction of regard is downwards and forwards.

BOTTOM HOLING IN A NARROW SEAM.

These photographs were taken on the surface. The man posed himself, and I did not alter his position in the least. Notice the direction of visual regard.



FIG. 16.—THE SEMI-RECLINING POSITION.



FIG. 17.—THE FULL RECLINING POSITION.

The lower leg is drawn up a little and the lower shoulder rests on a pad of coaldust.

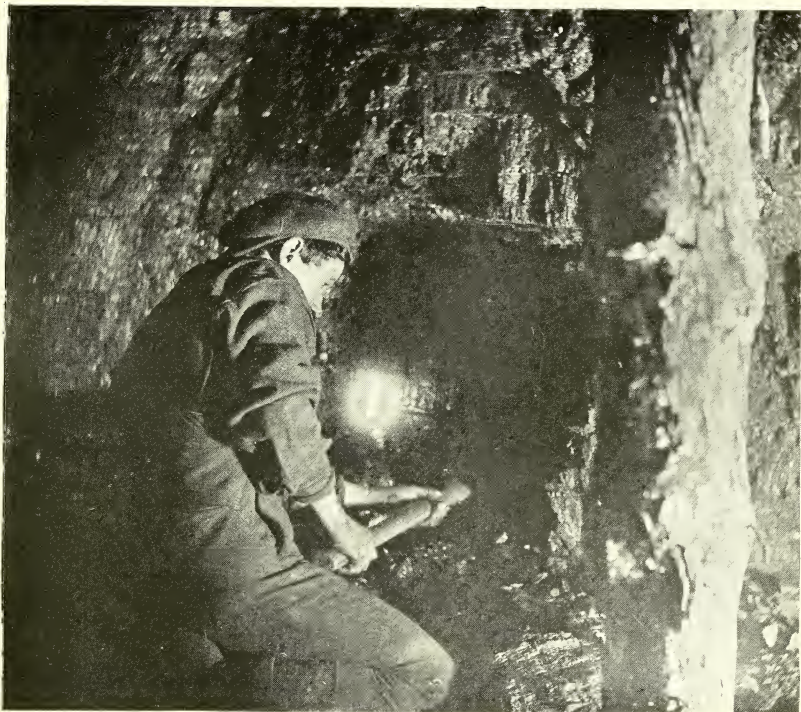


FIG. 18.—BOTTOM HOLING IN A SEAM $4\frac{1}{2}$ FT. THICK.

The collier is kneeling at his work and is holding his body a little inclined. The direction of vision is downwards. The light, a small open oil lamp, is placed on the ground close to the area of coal face worked. This photograph shows the method of holing usually employed in seams over 3 ft. thick.

varies from $2\frac{1}{2}$ ft. outside to 4 in. inside. The coal is struck with a small mandril, and every blow is placed. A good collier delivers his blows very rapidly and with a certain amount of regularity. I once saw an exceptionally skilful collier deliver 90 blows in the same number of seconds. When the coal has been undercut, a certain length of coal face is freed by cutting at right angles to the surface at the sides or ribs, and the coal is finally obtained by wedging the mass down from the top.

In all cases in bottom holing the collier strikes the coal at or below the level of his eyes. He utilises all his strength, and to do so has to allow the mandril a full swing; if he struck the coal above the level of his eyes he would only be utilising half his strength, and the difference between the two blows may be compared to the difference between a full and a half shot at golf. The man fixes a point on the coal which he is going to strike, and keeps his eye so fixed until the blow is struck; there is no more need for him to look upwards to follow the swing of the pick than there is for a carpenter to follow the swing of his hammer when he is about to strike a nail. If the portion of the coal to be worked is above the level of the eyes the collier moves his position until he is level. I have myself had several trials at holing in the various districts which I have visited, and have always asked the men to explain carefully to me their method of work. All the men I have seen struck the coal with a full swing of the pick at a point at or below the level of their eyes.

In some seams middle or top holing is necessary. Here, owing sometimes to a layer of clod between two seams of coal or at other times because the coal is much softer in some places or because the top rock is much softer than the bottom, the holing is done in that place which offers the least resistance to the pick. In the Forest of Dean the 20 in. coalseam is separated from a seam of Shaftel coal 6 in. thick by a layer of fireclay. The holing is done in the fireclay, and the collier is able to kneel at his work. The point I wish to make quite clear is this—that in whatever position bottom or middle holing is necessary the collier need not and does not direct his vision upwards. I have discussed this point with many colliery managers, and they all agree with me. I will quote a short extract from Dr. Court's pamphlet (20):—"The statement that the miners have their heads and eyes directed obliquely upwards during the process of holing is contrary to fact." "Now

when a man is lying upon his side in a cleft of coal only 18 in. and less in height, and has to strike at a gradually diminishing surface of a few inches in height, where can he turn his eyes except straight before him to try and see what he is doing? He certainly does not turn them obliquely upwards" (p. 12).

In "cutting" the coal near the roof the house coal collier has to look up. This is only necessary in the steam coal pits in some cases, and I have been told by men suffering from nystagmus that they have had trouble when doing this. This class of work is also carried out by "rippers," who have to rip down the roof with their pick. This work is all done above the level of the eyes, and yet the relative proportion of men attacked is not so great as in the case of the labourers (Table 14). The influence of unnatural position has been made too much of in the past. One must remember that the men are accustomed from their youth onwards to work with ease in positions that the chance visitor to the mine finds impossible. In a mining village if a man wants to rest out of doors he "sits on his heels," a position which the ordinary man would find very uncomfortable. A miner from a thick seam would be quite unable to earn a good living in the thin seams of Somerset or the Forest of Dean.

Acrobats from constant practice can assume with ease positions which are impossible for the ordinary individual, while Indian fakirs accustom themselves to remain in one fixed position for hours without moving a muscle. It is all a question of practice, and the collier from long use can work with ease in positions impossible for the ordinary man. A collier has his interval of rest like other workers, and he is not compelled to remain continually in a constrained position. In South Wales the coal-getter not only cuts the coal but fills the tram and attends to the necessary timbering of his place, and in this manner obtains relief.

With regard to the different districts it may be said that in the Forest of Dean, in Somersetshire, and in the house coal pits of Wales, holing is common and nystagmus very rare. In South Wales generally there is little holing done, and yet cases of nystagmus are common. In the Midlands holing is the rule in many districts, and here nystagmus is frequent. In the south of Yorkshire holing is common, but there is no distinct relation between the frequency of the disease and the practice of holing. In statistics from 43 collieries I obtained the following:—



FIG. 19.—THIS PHOTOGRAPH SHOWS MIDDLE HOLING IN A SEAM $4\frac{1}{2}$ FT. THICK.

If this photograph is compared with the last it will be seen that the body is held more upright. The lens of the camera was uncapped before the man had taken his final position, and the lamp flame is apparently between the man's arms and the camera. The lamp really is in the same position as in fig. 18. This photograph also illustrates the method of drawing or pulling the coal down after it has been holed and freed at the sides (ribs).

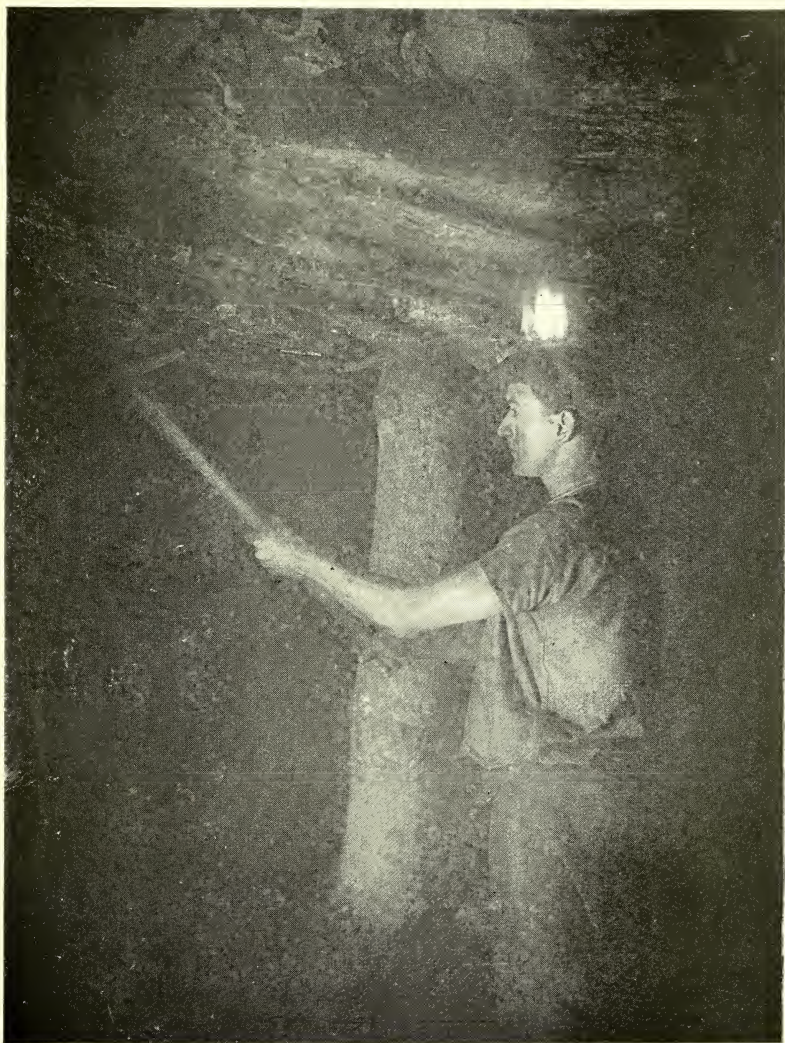


FIG 20.—COLLIER TOP HOLING IN A SEAM NEARLY 6 FT. THICK.

The direction of vision is slightly upwards.

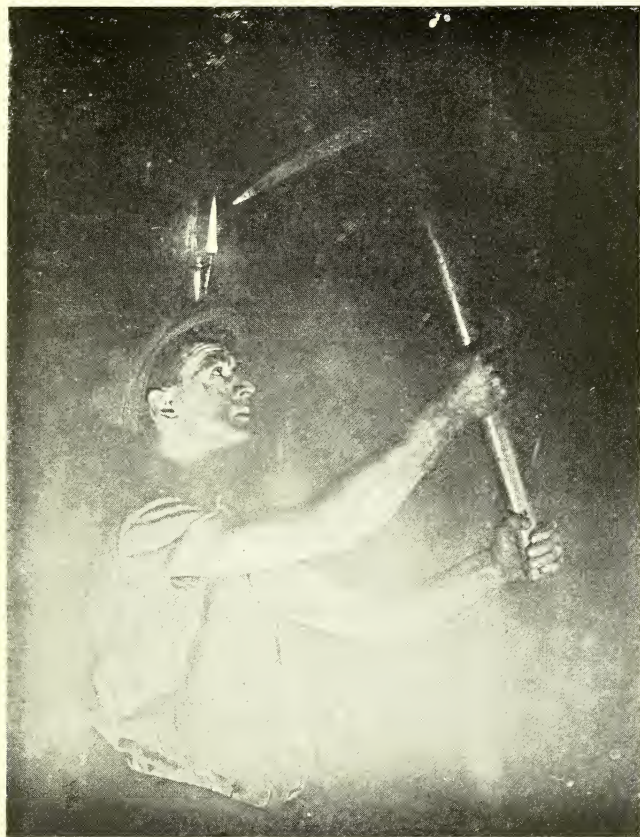


FIG. 21.—A COLLIER RIPPING TOP.

The direction of regard in this case is strongly upwards. A class of men, called rippers, generally do this work.

TABLE 15.

	Collieries.	Per cent. of nystagmus.
Much holing	30	·69
Little or no holing... ..	13	·79

TABLE 16.*—INFLUENCE OF HOLING.

Much holing	143	}	264 or 56·5 %
Some holing	121		
Little holing	31	}	203 or 43·5 %
No holing	172		

* This table applies to colliers only; a few cases where the man had formerly been a collier are added.

Of the 143 cases in which much holing had been done :—

TABLE 16A.

Holing on the side	104
Holing on the knees	29
Holing with the body inclined.....	10

Taking all my cases, 305, or over 50 per cent., did no holing. The loose use of the term “holing” is responsible for much confusion and difficulty in compiling statistics. Some managers limit the term to holing as performed in the Midlands, others call all undercutting of the coal holing.

The second method of winning the coal consists of taking advantage of the natural cleavage lines in the coal and relying on the pressure present to squeeze out the coal when one end has been freed. In comparison with the last method little skill is required except in the care of the roof. This method is the one chiefly employed in the steam coal pits of South Wales.

The third method consists in the use of mechanical coal-cutters, which perform the necessary undercutting. The men have only to bar or wedge the coal down from the top.

In one district, the Black Country, I have seen colliers cutting the coal above the level of their eyes. Here holes are cut in the top coal, and the man is continually directing his vision upwards. Fortunately, however, candles are used in these pits, and no nystagmus is found.

There is one way in which holing is of importance, and that is in the strain which it throws on the eyes in the absence of sufficient light. The collier has to place each blow of the mandril accurately or he loses so much work. I have often tested the skill of a collier by marking a small circle on the coal with chalk. In every case the centre of the circle was struck. When the collier lies in a cleft, of which the only three sides he can see are composed of coal, the amount of light which reaches the point he is striking is very small, owing to the great absorption of the light by the coal. Collier boys and fillers, whose chief occupation is to fill the trams with the coal obtained by the collier, often suffer from the disease. These workers have never done any holing, and have therefore never been subject to the strain of the elevator muscles of the eye, so strongly insisted upon by Snell and others. Cases are described under the heading of "Age" (page 40).

Timbermen and repairers frequently suffer from the disease. Their work is heavy, of a very skilled nature, and often very hazardous. They have to erect the timbers which support the roof and sides, and to repair any holes in the roof resulting from falls. It is this last occupation which is the difficult one, and one attended with considerable danger. The holes are often high, the danger of a fresh fall is great, and the hole itself is sometimes discharging gas so freely that it cannot be properly ventilated. Work has to be carried on at a great speed in order that the pit should not be stopped, and altogether the work is the hardest and most dangerous in the pit. In South Wales, where the pressure of the roof is so great, the work of a timberman is the most arduous, and it is from South Wales that the most of my cases of nystagmus in this class of workmen come. The timbermen have also to do much of their work above the level of their eyes, and it is in this class of workmen, much more than in the hewer, that the necessity for the upward glance, so insisted on by Snell as the prime cause of the disease, is present. The light obtained in these holes is very poor, owing to the fact that the safety lamp cannot be tilted to throw the light upwards. Some measurements I have taken of the amount of light falling on the place worked are given elsewhere (page 70). The fact that hauliers, and men connected with the haulage ropes, are attacked is fatal to the position theory. These men, whose time is spent in the main roads, have no occasion to depart from the erect attitude for any length of time. Some

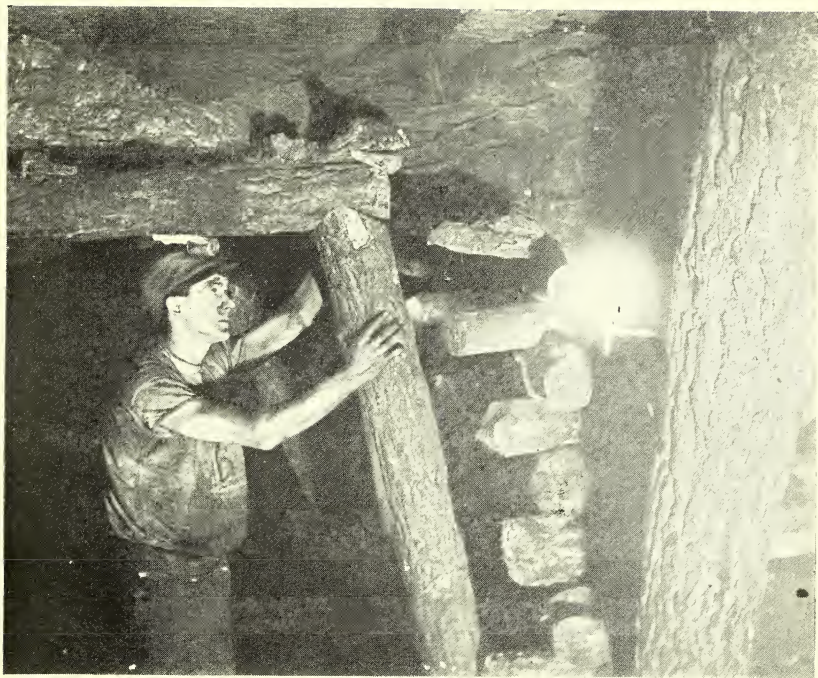


FIG. 22.—TIMBERMAN SETTING A PAIR OF TIMBERS.

The arm or upright post is \wedge -shaped on top in order to fit into a notch cut into the collar or horizontal post. The man is looking upwards while setting the post. The photograph was taken at the junction of a dip and main level, and part of the separating cog is shown.

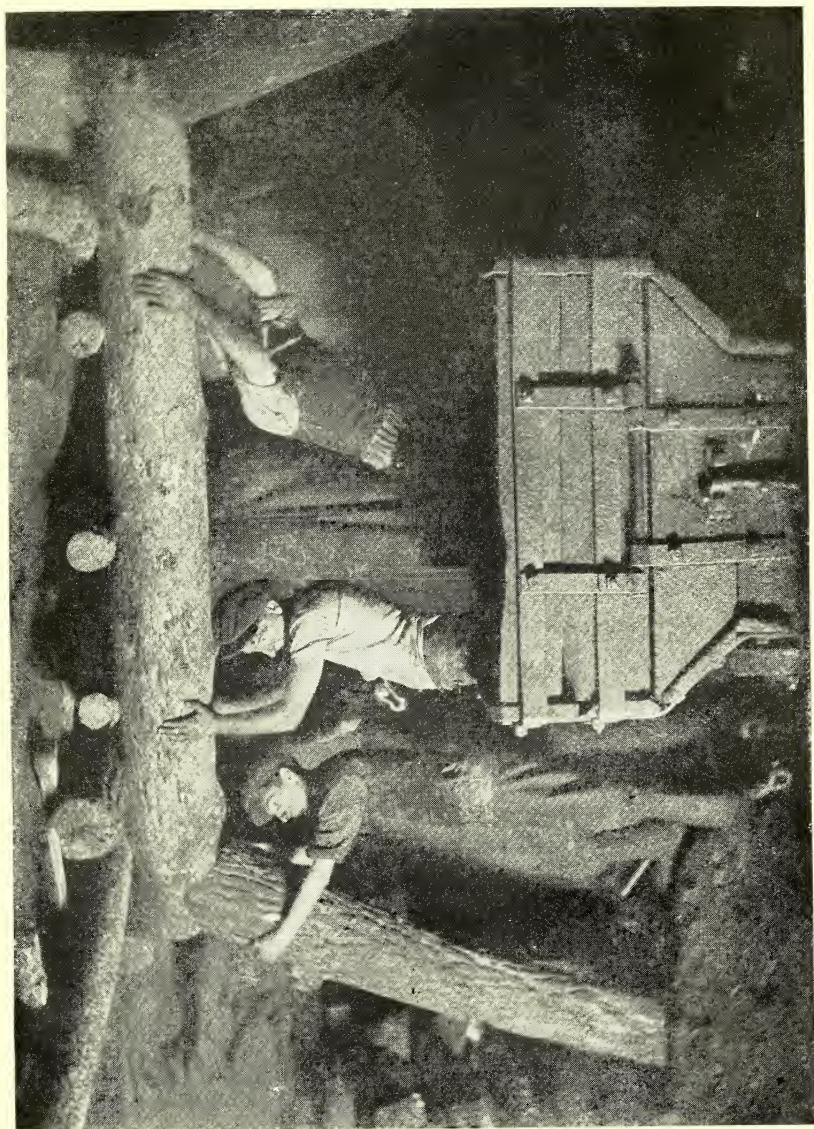


FIG. 23.—TIMBERMEN SETTING PAIR OF LARGE TIMBERS.

districts are very wet, and the lamps quickly become covered with mud, and the light given by them is consequently poor. I have taken measurements of the candle-power of the lamps taken from a dirty district, and I found that the lamps became as dirty as those used by colliers in a dusty place. I was once told by an old collier—a man whose power of observation was good—that at one time in a pit where he was working the hauliers were given gauze lamps of the Davy pattern because they were always breaking the glass of the other lamps, and that in this pit the hauliers were very badly affected with nystagmus. Table 14 shows that other grades are affected, and it may be said that no class of underground workmen is exempt.

THICKNESS OF SEAMS.

Most authors hold that nystagmus is more frequently found in men who work in thin seams, but my experience does not bear out this contention. It is, however, almost impossible to obtain the relative number of men working in each seam, especially in South Wales, where several seams, all varying in thickness, may be worked in one pit. The figures in the table are not so valuable as they might be for this reason.

TABLE 17.—THICKNESS OF SEAMS.

	Cases.
Less than 2 ft.	1
2 to 3 feet.....	47
3 „ 4 „	109
4 „ 5 „	121
5 „ 6 „	92
6 ft. and over	92

TABLE 18.—RETURNS FROM 43 COLLIERIES.

Seam.	No. of collieries.	Per cent. of nystagmus.
Less than 3 ft.	16	·81
3 to 4 feet	14	·54
4 „ 5 „	14	·80
5 „ 6 „	5	·58
Over 6 ft.....	6	·41

In this table, some of the collieries, having more than one seam, appear more than once.

Colliers go from one seam to another, and the question is

further complicated by the holing necessary in many thick seams. A man may say he is working in a 6 ft. seam and yet much of his time is spent under a ledge of coal less than 2 ft. in thickness.

The thin seams of Somerset and the Forest of Dean do not produce nystagmus, but the disease is frequent in thicker seams where safety lamps are used. The thinnest seam I visited was at Radstock, through the courtesy of Mr. G. E. J. McMurtrie. The seam ran from 12 to 14 inches in thickness, and all the coal was obtained by bottom holing for a distance of 18 to 24 inches in the clod under the coal. The men lay on their sides and placed their candles either in their caps or under the ledge of coal at which they were working. The direction of regard was always horizontally forward, and the men moved their bodies and not their eyes when they had finished holing the part of coal in front of them. I watched one particularly skilled collier for some time and noticed that his direction of regard was horizontally forward the whole time. This man told me he placed every blow accurately. In another part of the colliery the seams were 16 and 24 inches thick. In these thicker seams the men worked in a semi-reclining position, drawing up the lower leg and resting the shoulder on the bent-up knee. The head was held obliquely with its side pressed against the roof, and the direction of regard was downwards. I examined the men at the working face and only found one trivial case of nystagmus in a man who had recently come to the district from a safety lamp pit. This man was unaware that he had nystagmus, and assured me that he had never had any trouble with his eyes. There was no sign of nystagmus in any of the other men, and all told me they had never had any trouble with their eyes, and, in fact, had never heard of the disease. Mr. McMurtrie told me that he had never had any complaints from his men, and also that he had never heard of the disease in his district. The colliery was lit throughout with candles and was free from dust. The candles used were the common tallow variety, but recently wax candles (16 to the pound) have been introduced. I have tested the candles and found the wax candle a little over 1 candle-power, while the tallow candle varied from 1·3 candle-power to 2 candle-power according to the size of the flame, which can be regulated by carefully spreading the strands of wick. In this pit we have on the one hand low seams, bottom holing, and constrained position at work, and on the other hand a good light and no nystagmus.

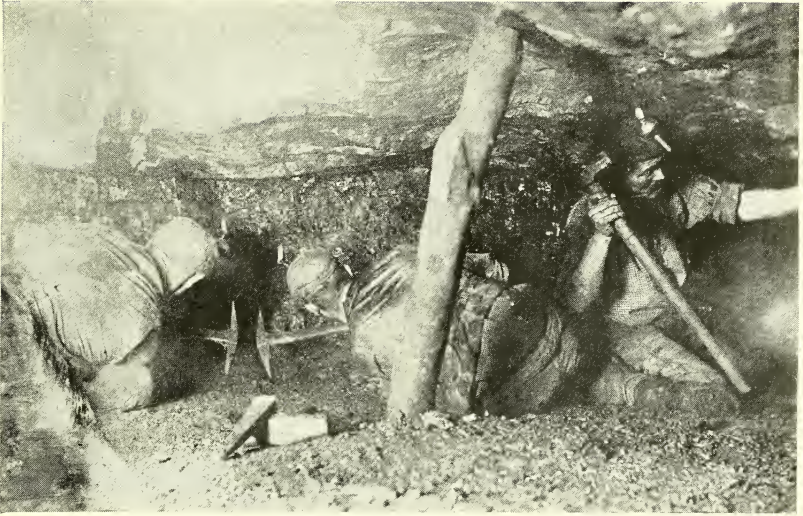


[*Photograph by S. Timothy, Pentre.*]

FIG. 24.—PHOTOGRAPH SHOWING MEN AT WORK IN A NAKED LIGHT PIT.

(Taken by Mr. Timothy, of Pentre, who has kindly given consent for its reproduction.)

The man on the right is cutting the coal and is in the position usually assumed by the collier in a seam of 3 to 4½ feet. The second man is engaged in holing in a layer of clod which intervenes between the two seams shown in the photograph. The safety lamp has been placed for effect in the centre of the picture and should be ignored; it seems very near the man's pick. The third man is engaged in putting up a post to support the roof. It will be noticed that both the colliers are looking down, while the third man is looking up. This and the next photograph were not taken for the purpose of this work, but form two of the well-known series of photographs of underground work by Mr. Timothy.



[*Photograph by S. Timothy, Pentre.*

FIG. 25.—THE COLLIERS ARE ENGAGED IN HOLING IN A THIN SEAM.

They have assumed what I call the semi-reclining position. The photographer has wanted to show too much, and so has placed the two men too close together. Note the light in the men's caps and the smallness of the pick used. The man on the left is resting his lower shoulder on the drawn-up leg; the position of the second leg is seen better in the second man. The direction of vision in both these men is downwards. The third man is engaged in setting up a post.

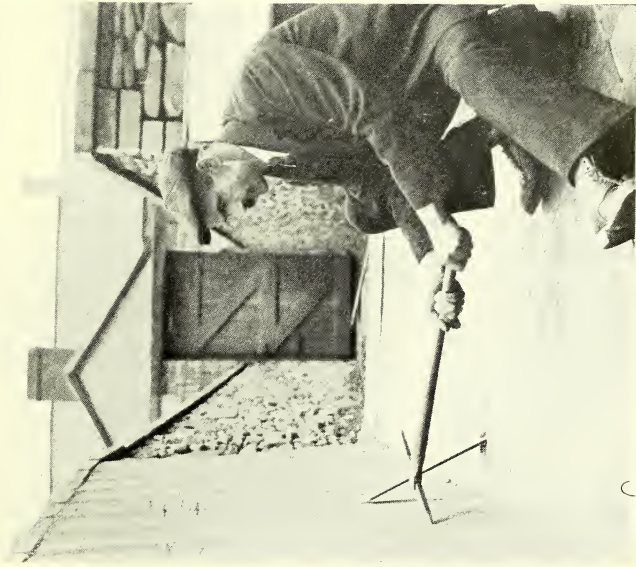


FIG. 26.—BOTTOM HOLING.

Photograph of a Yorkshire collier sitting on a buffet and holing in the bottom. Seam, 4 ft. Note direction of visual regard.



FIG. 27.—COLLIER IN A THICK SEAM, STANDING TO CUT THE COAL.

My experiences in the Forest of Dean were the same. I was fortunately able to see Mr. F. Brain, who is intimately connected with the whole coalfield, and he told me that he had only heard of one claim since the introduction of the Compensation Act, and that case was a lad who had recently come to the district. I went underground at Drybrook and saw the men at work in two districts of the pit. In the first district the seam (Lawry) was only 18 in. thick, and the men worked in a semi-reclining position. The coal is obtained by wedging down from the top after bottom holing has been carried out in the underlying fireclay to a distance of 30 to 36 inches. About 6 in. of the clod is removed. The fireclay is light in colour and reflects the light well. Wax candles (16 to the pound) are used. They are placed under the ledge of coal 18 to 36 inches away from the actual working place. The position assumed by the man is exactly the same as that usual in the Midlands, with the exception that in the Forest of Dean the men do not drag themselves under the coal. The narrowness of the seam, however, has the same effect, and the Midland hewer has as much room under his ledge of coal as the Forest man has in his thin seam. In the second district, the 20 in. coal, two seams of coal, separated by a fireclay 18 to 48 inches thick, are worked at the same time. The height of the working place varies, but at the time of my visit was under 4 ft., made up of 20 in. coal, 18 in. fireclay, and 6 in. of Shaftel coal. Here holing is done between the two seams, and the man is not compelled to assume the reclining position necessary in the thinner seam. The fireclay is darker than that of the thinner seam, and the candles were placed a little further away (from 3 to 4½ feet). I took several photometric readings, which are given on p. 66.

As a contrast I will describe a visit paid to the Black Country district in South Staffordshire, where the seams are the thickest in England and sometimes reach a height of 30 ft. In this visit I was fortunately able to meet some of the chief mining engineers in the district, and to obtain from them their experience with regard to nystagmus :—

Mr. Hughes, general manager of the Sandwell Park Colliery, told me that in the last 20 years he had not heard of more than half a dozen cases of nystagmus in the whole district, which employs about 8,000 men underground. "The disease is practically unknown." The whole district uses candles in the pit, with the exception of a few safety lamps used in coal headings.

Mr. Grazebrook, of Dudley: "I have only seen two cases in the whole district. One of these was a miner who was made to work with a safety lamp on account of a small ignition of gas in his district. The man complained that he was unable to work with the lamps, as they made his eyes jump so badly."

Mr. Holland, of Hamstead: "I have only seen two or three mild cases in all my experience. One case came from Yorkshire, and worked with us for two years. Ten months after his return to that district he developed nystagmus, and we have since had to pay our share of his compensation. This is the only case we have had to pay. We had another case who lost three weeks after working for a time in a coal heading with safety lamps; he then worked outside for a year, and finally returned to his old work."

Mr. Coles, of Sandwell Park: "I have had two cases—one slight and now back at work, the other a man who had been working with safety lamps for some time before his failure. In one or two districts I have had to introduce safety lamps, and it is from these districts that the cases have come."

I went underground at Sandwell Park and saw the men at work. There are two methods of obtaining coal. The one most commonly used is the following:—An area of coal about 9 yards square is supported by timber. At the margin of this area cuttings or spurns are made into the top coal. These spurns surround the area with small webs of coal left in between. The timber is then removed, and the coal falls or is assisted down by a shot. The spurns are holes about 6 ft. long, and 4 or 5 feet high; they are broad enough to take the miner's shoulders comfortably. The miner places his candle in these holes, and is able to put it within 18 or 20 inches of the place worked. He has to strike the coal above his head, and to do this must throw his head back and his eyes up. This is the position which Snell regards as the chief factor of the disease, yet none of these men have ever complained to the manager of trouble with their eyes. The other method is to drive a heading into the solid coal. No holing is necessary, but safety lamps are used, and it is from these districts that the cases of nystagmus have come.

It may be said that the greater part of the pit is lit with candles, and that the safety lamps are few in number. The seams are, of course, the highest in England, and sometimes reach the height of 30 ft. The candles used are common tallow, and each contains 10 strands of wick, which the men skilfully spread out with their thumbs so as to obtain an excellent light. I was able,



FIG. 23.—COLLIER CLEANING THE TOP OR TOP HOLING.

The eyes are directed upwards, but not to any marked extent. Seam, 4 to 5 feet.

after a trial, to obtain a flame 4 in. by $\frac{6}{8}$ at the base, and tested with the photometer a candle gave from 1·3 to 1·8 candle-power, according to the size of the flame.

As a contrast to these collieries, a visit to the Shelton Iron, Steel and Coal Company Limited, Stoke, will be described. I paid a visit to these collieries through the courtesy of Mr. G. P. Hyslop. The company employs 2,600 men underground, and there are two sets of workings—one about 3,050 ft. deep, hot (temperature 89 degs. Fahr.) and dusty, Protector lamps used throughout. The other set of workings is about 700 ft. deep, and Protector and Ackroyd and Best lamps are used. All lamps have double gauzes. The seams are 10 in number, and vary from 3 to 4 feet and 5 to 7 feet in thickness. About one-half of the coal is got by bottom holing. Twenty-seven cases of nystagmus have been certified in the last three years.

	Men (proportion).	Cases of nystagmus.
Deep workings	18	22
Shallow workings	5	5

One-twelfth of the total output is obtained from one district in which coal-cutters are used, and from this district no cases of nystagmus have yet been certified.

CHAPTER V.

Conditions Determining the Occurrence of the Disease*—*Continued.*

ILLUMINATION.

THIS chapter will be divided into three sections, the first dealing generally with the subject and with statistics from the various coalfields, the second containing an analysis of my own figures, and the third giving photometric measurements taken at the coal face and of the candle-power of the safety lamp under varying conditions.

SECTION 1.

Miners' nystagmus is practically confined to coalmines, although a few cases are found in ironstone mines, where, owing to the presence of thin coalseams, safety lamps are used.

(1) Case 477. A road layer, age 54, working in an ironstone pit with safety lamps. I saw him six months after the onset of the disease, and was then not able to detect any nystagmus. He had all the subjective symptoms, and had been certified in the usual way.

(2) I had a letter from a man working in an ironstone mine in Yorkshire giving the same kind of history. This mine was worked with candles. (*See* page 123).

In purely metalliferous mines there has been no case of nystagmus recorded up to the present time. In reply to a letter of mine asking for information, Dr. J. Telfer Thomas, of Camborne, kindly sent me the following:—

"I have been in practice in the mining district of Cornwall for the past 23 years, and have never seen a case of miners' nystagmus there. . . . It does not attack tin miners."

In metalliferous mines, candles or open lamps are used, while in a coalmine safety lamps are often necessary. The naked light coalmine comes midway between the safety lamp pit and the

* Much of the matter contained in this chapter has already been published, and is reproduced by permission of the Council of the Institution of Mining Engineers ("Illumination at the Coal Face, with Special Reference to the Incidence of Miners' Nystagmus," a paper read by the author before the South Staffordshire and Warwickshire Institute of Mining Engineers, October 21, 1912).

metalliferous mine, having the general blackness of the former and the good light of the latter. Manifest nystagmus is common in the safety light pit, rare in the naked light pit, and absent in the metalliferous mine. The table will show at a glance two of the main factors in the production of miners' nystagmus.

TABLE 19.

Character of mine.	Light used.	Nature of surroundings.	Prevalence of nystagmus (manifest).
Safety lamp coal pit	<i>Poor. rarely equal to .5 cp.</i>	<i>Marked blackness</i>	Common
Naked light coal pit	Generally 1 cp.	<i>Marked blackness</i>	Rare
Metalliferous mine	Generally 1 cp.	Blackness absent	Unknown

Illumination in a confined space is very largely dependent upon reflection from the containing boundaries. An illustration, given in Trotter's (121) *Illumination*, page 24, will explain the great importance of this reflecting power. "If lights amounting to 100 candle-power are placed in a room having walls, floor and ceiling of a reflecting power of 80 per cent., one-fifth of the light will be absorbed and four-fifths reflected. This reflected light is for all intents and purposes a new light of 80 candle-power. It will fall on the sides of the room; one-fifth will be lost, and four-fifths—that is, 64 candle-power—will be reflected. The total effective candle-power in the room will be

$$100 (1 - .8 - .8^2 - .8^3, \&c.);$$

$$\text{Now } (1 - .8 - .8^2 \&c.) \text{ carried } ad \text{ infinitum is } \frac{1}{1 - .8} = 5.$$

The total effective light in the room is therefore the same as if the walls and ceiling had been black, and 400 lamps of 1 candle-power each had been spread evenly over the walls, in addition to the original 100 candle-power." "This," as Mr. Trotter remarks, "is

worth having." This diffused reflecting power is practically absent at the coal face. The coal itself is black, the floor is covered with coal and coaldust, the roof, owing to the shadow cast by the bonnet of the lamp, is in darkness, while any little reflection from the gob is stopped by the back of the miner himself.

I have taken several measurements of the reflecting power of the coal in different coalmines. These measurements are very difficult to obtain, and are only approximately true. They were all taken with a Trotter photometer, specially adapted for me to use in coalmines, by Messrs. Everett, Edgcumbe and Co., Hendon. The actual measurements will be given later, and at present it will be sufficient to say that the absorption at the coal face varies from 86 to 97 per cent. of all the light falling on the surface. These figures prove conclusively that practically all the light which falls on the coal face is absorbed. They also show that the amount of light reflected from the facets is very small.

STATISTICS FROM THE VARIOUS AUTHORS.

Very few of the writers on the subject have given the relative number of cases from safety lamp and naked light pits respectively. Court is by far the most definite on the point. In his pamphlet (20, p. 10) he says: "The insufficient light of the safety lamp is the chief, if not the sole cause of nystagmus." The results of his investigations are given on p. 28. Romée lays great stress on the improvement obtained with a better light, and some of his figures are given on p. 29. Snell says the cases from both classes of pits are nearly equal, but most of his cases come from safety lamp pits. Stassen (108) makes the same statement, but acknowledges that the cases in naked light pits are less severe. Dransart (35) quotes figures of an examination of a pit at Anzin in which the Davy lamp replaced an open lamp. Nystagmus was found in 5 per cent. of men employed when a lamp *à feu* = 1 candle-power was used, and in 15 per cent. of men employed when a Davy = .29 candle-power was used. Nieden (p. 39, 65), gives an analysis of an examination of 11,145 workmen, of whom 405 showed nystagmus. He has arranged the tables to show the proportion from each pit, and from his figures I have extracted the following table:—

Purely safety lamp pits	349 or 4·7 per cent. of workmen employed
Lamps and open lights	50 „ 1·6 „ „ „
Open light pits.....	6 „ .65 „ „ „

He calls attention to the geographical distribution of nystagmus, and says the percentage varies from 7·6 in the north-west district [where safety lamps are almost entirely used] to ·4 in the south-east [where open lights are used almost entirely]. The words in brackets are mine.

In a district where naked light pits and safety lamp pits are close together, cases of nystagmus are found in both classes of pit, chiefly for the reason that men migrate from one class of pit to the other, often deliberately because they are unable to work any longer with the safety lamp. Several cases illustrating this point will be quoted. Nystagmus undoubtedly does occur in miners who have always worked with candles, but manifest or symptomatic nystagmus is rare. The differences between the safety lamp and the candle and between the safety light pit and the naked light pit, must now be described. The candle gives more light, often more than one candle-power, remains constant during the day, throws no shadows, and, most important of all, can be placed very much nearer the coal face. In this connection the law of inverse squares must be remembered, the illumination diminishing in intensity inversely with the square of the distance; thus one candle-power at 1 ft., four candle-power at 2 ft., and nine candle-power at 3 ft., all give equal illumination. The safety lamp gives less light, rarely more than ·5 candle-power, quickly becomes dirty, throws shadows, and must be placed out of reach of the pick. The bonnet and oil reservoir cut off much of the light and produce an area of darkness above and below the lamp.

In South Wales there are several twin collieries, one working the steam coal measures with safety lamps, the other the bituminous coal with naked lights. Comparison between two adjoining pits will now be given.

Safety Light Pit.

Patterson safety lamps, burning a mineral oil of a flash point 260 degs. Fahr. are used throughout in this pit. The average candle-power of 60 clean lamps was ·42. The seams vary from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet, and the method of working is the longwall system. Owing to the great pressure the coal is readily got and no holing is necessary; the lines of cleavage are looked for and the coal barred down.

The Naked Light Pit.

Candles are used at the face, and open lamps in the main roads, while the haulier carries a large lamp. Candle-power of candles used is 1·1, of the lamps 2 to 3, and of the hauliers' lamps 3 to 4. The seams run from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet, and the coal is hard to get. There is no holing as understood in the Midlands, but all the coal is undercut for 2 or 3 feet, and obtained entirely with the aid of the pick. The collier here is a more skilled workman than his fellow of the steam coal pit, and has to rely more on his own efforts.

	Men.	Cases of nystagmus.
Safety light pit	1,900	9
Naked light pit	620	1

Similar pits in another district:—

	Men.	Cases of nystagmus.
Safety light pit	1,850	9
Naked light pit	820	0

COLLIERY STATISTICS.

I have obtained, through the great kindness of colliery proprietors, statistics from a large number of collieries. These statistics are included in the tables shown. They are, to a certain extent, contradictory, and pits working under apparently the same conditions are very unequally affected. I am quite convinced of one point, and that is, that if nystagmus is prevalent in any

district, men who would otherwise continue working, are acted upon by suggestion, quite without their knowledge and without any inducement on the part of others, and help to swell the ranks of the unemployed. You very rarely find a solitary case at a colliery unless he has come from a lamp pit to an open light pit. I have often noticed that men will fail in batches. I will quote the case of a man (case 497), who had an injury to his ankle; he was told by his doctor that he had nystagmus, and the result was that although he had never had any symptoms before, he was unable to continue working underground and had marked symptoms afterwards. In the purely naked light districts of the Forest of Dean and Somerset, nystagmus is unknown. Mr. McMurtrie, of Radstock, Somerset, has not heard of the disease in his district. Mr. F. Brain, Forest of Dean, writes: "I am in pretty close touch with the greater part of the collieries in this district, and I have so far, since the Compensation Act has been in force, known of one claim. Open lights are used entirely here." In the Black Country district, where open lights are generally used, it is very rare (*see* p. 49). In the two former districts all the coal is obtained by holing in thin seams, and in the house coal pits of South Wales also, holing is common and nystagmus very rare. On the other hand, when extensive holing is carried out with safety lamps, nystagmus is common, and I believe that the holing has an influence in these districts; but see Table 15 (p. 45).

Through the courtesy of the Home Office, I am able to give the figures for Scotland apart from those of the rest of the kingdom.

TABLE 20.

	Scotland.	Rest of kingdom.
Number of cases of nystagmus.....	55	1,563
Percentage of cases to men underground	·05	·21
Percentage of safety lamps used	28·2	91·6

Nystagmus is four times more common in England and Wales, and lamps are used three times more frequently than in Scotland. In addition, all the nystagmus cases may have come from the safety lamp pits.

TABLE 21.—COLLIERY STATISTICS.

District A.

Pit.	Men.	Nystagmus cases.	Light and oil used.	Seam.	Holing.	Remarks by manager.
				Feet.		
1	508	0	Candles	6	Little	"There have been one or two cases." 3, 4, 5, same company. "We have had three or four men in No. 5 pit who complained of their eyes. They were transferred to pit 4 with beneficial results."
2	1,556	?	Candles	5 to 6	Much	
3	770	0	Candles	5 to 6	Little	
4	880	1	Candles	3 to 5	Little	
5	337	1	Marsaut Colzaline	5 to 6	Some	
6	700	6	Ackroyd and Best petroleum	7 to 8	Little	
7	800	3	Ackroyd and Best	4½ to 7½	Much	

District B.

1	1,685	10	Ackroyd and Best Protector some candles	5½ to 8	Some	Half coal obtained by holing.
2	1,020	6	Protector spirit	2¾ to 8	Much	"Five out of the six cases worked with lamps. The other man has had a general breakdown." "Most of the cases came from a seam over 7 ft." "21 cases worked at the face, of the 23 cases only two occurred where naked lights were used"
3	1,500	6	Protector lamps candles	3½ to 6	Much	
4	1,100	16	Protector spirit	4 to 7½	Very little	
5	1,280 (555 at the face)	23	Marsaut 399 candles 156	3 to 4	Not much	

District C.

1	100	0	Lamps candles	16 to 26	Little	(3) A group of five collieries. "No cases. This I attribute to the fact that they are naked light pits."
2	80	0	Lamps	4	Some	
3	564	0	Candles	12 to 30	Little	
4	?	0	Candles	—	—	
5	?	0	Candles	—	—	
6	?	0	Candles	—	—	
7	800	0	Candles a few lamps	15 to 30	None	
8	800	2	Candles a few lamps	15 to 30	None	

TABLE 21—cont.

District D.

Pit.	Men.	Nystagmus cases.	Light and oil used.	Seam.	Holing.	Remarks by manager.
1	1,967	12	Marsaut mineral colza	Feet. 3 $\frac{3}{4}$	Much	17 per cent. got by coal-cutters. See p. 75. All coal got by hand.
2	1,500	31	Ackroyd and Best	4 $\frac{1}{2}$ to 5	Much	
3	1,988	7	Ackroyd and Best	4	Much	
4	1,659	14	Marsaut	4 to 5	Much	
5	1,006	4	Marsaut	4 $\frac{1}{2}$	None	
6	1,094	3	Ackroyd and Best	3 $\frac{1}{2}$	60 per cent.	
7	650	0	Marsaut	5 $\frac{1}{4}$	Much	
8	1,300	34	Candles	4 $\frac{1}{2}$	Much	
9	1,053	4	Candles	5	Much	
10	263	0	Candles	3	Much	

District E.

1	450	9	Cambrian	3 to 4 $\frac{1}{2}$	Little
2	1,400	22	Cambrian	4 to 6	Little
3	2,500	14	Ackroyd and Best	4 to 5	Little
4	1,500	10	Ackroyd and Best	4	Little
5	1,900	9	Patterson	3 to 4	None
6	620	1	Candles	3 to 4	Much

District F.

1	1,200	32	Mueseler	6 to 9	None	Seams inclined. Lamps hand cleaned.
2	2,800	65	Evan Thomas	4 to 5	Much	Lamps hand cleaned.

District G.

1	1,800	7	Patterson	6	None	Group of collieries.
2	3,300	23	Thomas and Williams	6	None	
3	231	1	Candles	2 to 3	Much	
4	1,850	9	Clanny	4 to 5	None	Group of nine collieries.
5	820	0	Candles	2 $\frac{1}{4}$ to 3 $\frac{1}{4}$	Much	
6	6,400	15	Thomas and Williams	5 to 6	None	

TABLE 21—*cont.**Anthracite District H.*

Pit.	Men.	Nystagmus cases.	Light and oil used.	Seam.	Holing.	Remarks by manager.
1	1,200	0	Lamps	Feet. 3 to 4½	None	
2	641	1	Protector	2¾ to 3½	None	
3	338	1	Proctor	3½ to 5	None	
4	191	0	Candles	5	None	
5	500	1	Ackroyd and Best	3 & 5½	—	

District I.

1	?	0	Candles	5	Much	"Bottom holing to 4 ft. in every working place."
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District J.

1	2,938	10	Mueseler	5 & 9	Much	"Half the cases have never worked on the coal."
2	1,342	31	Safety	4½	Little	"Up to recently we used the ordinary safety lamp, now we use Ackroyd and Best."
3	?	0	Candles	4½	Much	
4	371	3	Marsaut	3½	None	All coal machine cut.
5	1,666	23	Marsaut	5½	None	
6	5,000	25	Marsaut and Deflector	3½ & 6½	Some	Coal-cutters used.
7	1,334	2	Ackroyd and Best	2½	None	"All coal got by machines."
8	1,770	20	Marsaut	4	None	
9	2,098	21	Protector	4	Little	"Some holing on the knees."
10	1,700	4	Protector some candles	2, 3 & 4	Much	Some machines used.
11	682	21	Marsaut	2 to 3	—	"Men sitting on stools undercut to distance of 18 in."

District K.

1	4,000	21	Cambrian lamps	5 ft. 6 in.	Very little	A group of five collieries.
2	200	0	Candles	2 ft. 9 in. to 22 in.	Much	

SECTION 2.

In my own series most men had worked with safety lamps or had used safety lamps almost continually. Out of 600 cases, 591 had worked with safety lamps and only nine with candles only.

TABLE 22.

	No.	Latent.	Receiving compensation.
Safety lamps.....	577	111	466
Candles	23*	7	16

* Of these 23 cases, 14 had worked for some time with safety lamps.

I have separated the cases in my own district from the rest of my series because in this district I have seen every case that has been certified and know the relative number of men employed in the open light and safety light pits. I have also taken photometric measurements of the lamps and candles from these pits and of the illumination present at the coal face.

TABLE 23.

	Men.	Relative number of certified cases of nystagmus.	Relative proportion.	Average candle-power of illuminant.	Average illumination at the coal face in foot-candles.
Safety lamps ...	88 or 7·3	46	6·3	·35	·018 or 1
Candles	12 or 1	1	1	1	·09 or 5

Nystagmus is then 6·3 times as common among men who work with safety lamps. I cannot help pointing out the relationship these figures bear to the relative amount of light given by the candle and safety light at the coal face.

I have never seen nystagmus in hauliers in an open light pit. These men use a lamp of about 3-candle power. I had an interesting note from a manager who had charge of the two classes of pit:—"We have had three or four cases in the 7 ft. mine (lamps) who complain of their eyes troubling them, and who have been transferred to the — mine (candles), with, as far as we can learn, beneficial results to them, having heard nothing more from them."

Illustrative Cases from Candle Pits.

(Case 6) In this case the onset came after the shock of an explosion. The case is a most unusual one, and is described on p. 7.

(Case 30) Collier, age 35, underground 25 years "I have worked for the last five years in a candle pit, and before that I was two years in a safety lamp pit. All my work is hammer and drill work, throwing great strain on the eyes." Blue eyed, fair haired man with marked nystagmus. Hypermetropic astigmatism.

(Case 371) Collier, age 58, underground 30 years. The man was so deaf that I could get no history, but I was told he had worked almost all his time with naked lights.

(Case 424) Collier. Last six months in a candle pit. Before this in a lamp pit. In all, eight years with lamps and eight with candles.

Cases 509-521 inclusive, all came from a naked light pit. (See p. 75.)

Latent Cases.

(Case 43) Collier, age 33, underground 22 years. This man has only worked two years in a safety lamp pit. No symptoms of any kind. The nystagmus was noticed on examination.

(Case 50) Collier, age 40, underground 26 years. Candles always. No symptoms. Nystagmus noted on examination. Marked myopic astigmatism.

$$- 3$$

$$+ \quad - 3.5 \text{ in both eyes.}$$

(Case 52) Collier, used to working in thin seams. No symptoms. Nystagmus found on examination. Age 44, underground 30 years. Has worked seven years with lamps.

(Case 104) Collier, age 40, underground 17 years. Nystagmus found on examination. "I am as good a collier as anybody." Two years in a safety lamp pit.

(Case 269) A very slight case. The man was a collier who had recently come to a naked light district from a safety lamp pit. He was unaware that he had nystagmus, and told me he never had any trouble with his eyes.

(Case 421) Collier, age 44, underground 32 years. No symptoms. Candles all but four years.

(Case 427) Collier, 42, underground 21 years. Has worked 19 years with lamps and the last two with candles. No symptoms.

(Case 484) *See* page 106. Collier, 63, underground 40 years, lamps 20 years. No symptoms of nystagmus, but of failure of sight due to a cataract. Nystagmus present. One eye lost 35 years ago.

Cases who were Obligated to leave a Safety Lamp Pit.

(Case 7) Collier, age 30, underground 17 years. "I have worked all my life until lately in a safety lamp pit. Twelve months ago I noticed my eyes were getting weak, and I went to a candle pit for this reason. I was only able to work on for nine months."

(Case 13) Collier, age 38, underground 18 years. "I went to a candle pit because I was unable to continue working in a safety lamp pit. I was able to work there for another 14 months, but had to give up eventually."

(117) Collier, age 44, underground 32 years. This man has worked 28 years with safety lamps and four with candles. During the last four and a-half years he has worked for four years with candles and in four different pits. This latter fact in a man of his age is interesting, and I found out with some difficulty the following facts. He has suffered from nystagmus for the last five or six years, having worked up to that time continuously in a safety lamp mine. He was unable to continue, and so went to a candle pit. He worked in this pit for three and a-half years, and then returned to a safety lamp pit, where he was only able to work for six months. He returned once more to another candle pit, and was able to keep on for a little over six months. He had stated, on application for work at each pit, that he had not suffered from nystagmus, and hence the reluctance to give me the history. This case also illustrates the fact that if the man struggles on for years he is certain to have a very severe attack. He suffers from such marked headache that he has told me he thought "he would go out of his head." The nystagmus is very marked, rotatory, and present even when the eyes are depressed 20 degs. below the horizontal. This last symptom is very unusual, and is a sign of the marked severity of the attack. He also suffers from marked nictitation—so much so that his wife nicknamed him "Blinking Joe" some years ago.

(189) Collier. Has worked all his life in a safety lamp pit, except for the last four months spent in a candle pit.

SECTION 3.

ILLUMINATION AT THE COAL FACE.

In the following measurements taken at the coal face a Trotter photometer, specially adapted for use in coalmines by Messrs. Everett, Edgcumbe and Co., Hendon, was used in all cases. My method has been to take measurements of the light actually falling on the working face under normal conditions, and all measurements with the exception of one series have been taken in working hours. I ask the collier the area over which he would work without altering the position of his light. Measurements distributed over the top, middle and bottom of this area of coal face are taken by reading the amount of light reflected by a standard white screen placed against the coal. These measurements give the actual amount of light falling on the coal face in foot-candles. In the open light pits I have often replaced the candle by a safety lamp and taken the readings again. In many cases, however, the lamp had to be placed further away from the coal face than the candle, and a much lower reading was obtained, sometimes only one-tenth of that given by the candle. The highest reading of the illumination at the coal face was with the candle, .35 of a foot-candle; and with the safety lamp, .035 of a foot-candle.

A few definitions will be given:—

A standard candle burns 120 grains of sperm every hour, and is said to be of 1 candle-power.

A foot-candle is the illumination produced by 1 candle-power at a distance of 1 ft.

The intensity of illumination varies inversely with the square of the distance of the source of light; thus one candle at 1 ft., four candles at 2 ft., and nine candles at 3 ft. all give equal illumination.

If the surface illuminated is inclined to the direction of the rays of light, the illumination will vary with the cosine of the angle of incidence of the light. If the angle is 60 degs., the cosine of 60 degs. being .5, the surface will only receive half the illumination it would have received had it been normal to the rays of light.

The surface brightness of any surface is the amount of light reflected by that surface, and depends

- (1) On the amount of incident light, a variable factor.
- (2) On the albedo or reflecting power of that surface, a constant factor (*see* p. 71).

NAKED LIGHT PITS.

A.*

Collier cutting coal at the rib in a seam 4 ft. thick. The candle was 24 in. away from the coal face, but a safety lamp could not be placed nearer than 33 in. Readings of both lights were taken.

Coal face.	Candle.	Safety lamp.
3 in. above floor	·185	·025
18 in. „ „	·17	·03
24 in. „ „	·075	·03
36 in. „ „	·055	·02

B.

Light falling on a working place 3 ft. 8 in. away from candle, which was raised 33 in. above the ground. A safety lamp was placed in the same position and corresponding readings taken.

	Candle.	Safety lamp.
Light falling on ground at coal face...	·06	·006
Light falling on coal 2 ft. above ground	·12	·024

C.

Conditions of work.	Readings at face.
Collier holing, candle 4 ft. from face.....	·1
Limit of working place.....	·065
Collier holing, candle 4½ ft. away	·04
	(candle snuffed
	·075)
Limit of working place.....	·025
Collier holing, candle 4 ft. away.....	·05, ·055

Average light on working place, ·056 of a foot-candle.

* All readings are given in foot-candles.

D.

Naked Light Colliery in the Forest of Dean.

The colliers were holing in an 18 in. seam, and the candles were placed from 18 to 36 inches away from the coal face.

Conditions of work.	Readings.
1st collier holing, candle 24 in. away.....	·21
2nd „ „ „ 18 „ „	·35
3rd „ „ „ 18 „ „	·16 (candle dying down)
4th „ „ „ 24 „ „	·065
5th „ „ „ 36 „ „	·065 (limit of place ·04)
6th „ „ „ 30 „ „	·1

Average reading at the coal face, ·14 of a foot-candle.

Twenty-Inch Seam.

In this seam, the distance of the candles from the face was from 2 to 4½ feet. The men were all engaged in middle holing. The following readings were taken throughout each man's place at varying distances from his source of light.

	Readings.
1st working place	·04, ·1, ·12, ·19
2nd „ „	·045, ·075, ·095, ·11
3rd „ „	·02, ·04, ·12, ·29
4th „ „	·05, ·055

Average reading, ·1 of a foot-candle

E.

Naked Light Pit in South Wales.

In this pit several measurements were taken over the area of face worked by each collier.

	Readings.
1st working place	·035, ·05, ·045, ·115, ·18, ·095
2nd „ „	·115, ·135, ·075
3rd „ „	·075, ·09, 075, ·05, ·025, ·02

Average reading at coal face, ·08 of a foot candle.

In the third working place a safety lamp was placed as near as possible to the position of the candle, it could not be placed in the same position. The corresponding readings were .012, .015, .015, .012 of a foot-candle.

SAFETY LAMP PITS.

A.

Men holing in a seam $5\frac{1}{2}$ ft. thick to a distance of 5 ft. The lamps were all placed at least 3 ft. away from the coal worked. The readings were taken throughout a long area of face. The distance of the lamp from both ends of the length of coal face worked is given. Thus if a collier is working over a length of face A—B, and the lamp is placed at C, then the distance A—C and B—C is given. In the first instance A—C is 3 ft. and B—C 4 ft.

	Distance from lamp.	Readings.
	Ft.	
1st collier	3 to 4	.025, .02, .015
2nd „	$4\frac{1}{4}$ to 6	.03, .015 (bar in way), .022, .02
3rd „	5 to 7	.032, .012
4th „	4 to $5\frac{1}{2}$	.025, .0175
5th „	3 to $4\frac{1}{4}$	.03, .025, .025, .02
6th „	$3\frac{3}{4}$ to 5	.03, .025

Average reading at the working face .022 of a foot-candle.

The candle-power of the lamps of these men was tested, and the following results were obtained :—

.26, .3, .32, .18, .36, .28, and one filler's lamp .16.

Average candle-power of lamps used at the face, .25 candle-power.

B.

In this pit readings were taken at the actual part of the coal face worked when I entered the stall.

	Distance of lamp.	Reading.	Candle power of lamp.
Stall 1.—	Ft.		
Boy driving wedge	8	.001	.1
Collier cutting coal	$2\frac{1}{4}$	.03	.18
Stall 2.—			
Collier cutting coal	$5\frac{1}{2}$	.0125	—
Stall 3.—			
Collier getting coal	5	.02	.22
Boy helping	$4\frac{1}{4}$	.02	.2

Average reading at the face, .016 of a foot-candle. Average candle-power of lamps, .175.

C.

In this pit readings were taken in a narrow conveyor face and in a thick seam.

1. *Narrow Conveyor Face.*

The first collier was working over a length of face of $11\frac{1}{2}$ ft., with the lamp midway between the two ends.

·01	·015	·0175	·015
·01	·0175	×	
·0125		·02	·015

Average reading, ·015 of a foot-candle.

The lines are intended to represent the area of coal face worked and the position of the lamp is indicated by a cross. The lamp must be considered as standing out from the diagram at a distance of $5\frac{1}{2}$ ft. from the coal face. The figures are placed approximately in the positions at which the readings were taken.

The second collier was working over 13 ft. of face. The lamp was 6 ft. 2 in. from the nearest point on the face, and was 9 ft. from one end and $7\frac{1}{2}$ ft. from the other end of the face worked.

·01	·01	·0175	·005	·02	·0125	·0075
·0125	·012	·015	·005 ×	·02	·0125	·0075
·012	·012	·015	005	·0125	·0125	·006

The average reading was ·012 of a foot-candle.

* Measurements in this column were all taken in the shadow cast by the lamp standard.

The third collier was working over 12 ft. of coal face.

·015	·015	·025	·03	·02	·015	·01
·015	·025	·03	× ·03	·0175	·015	
·015		·025	·02	·02	·015	·008

The average reading was ·018 of a foot-candle.

The average reading over the three places was ·015 of a foot-candle.

2. *Barry Face. Seam $5\frac{1}{2}$ ft.*

First man working over $17\frac{1}{2}$ ft. of coal face. Lamp 2 ft. 10 in. from the centre of coal face. Flame 14 in. from roof.

READINGS.

009	·009	025 ×	·035	·02	·009
007	009	02	·03	·0175	·008
009	·011	·022	·012	·01	·008

Average reading, ·015 of a foot-candle

Second collier working over 9 ft. of coal face. Lamp placed on a post 1½ ft. above the ground.

·01	·01	·005*
·01	·01	·02
·005	·015	·02 ×

Average reading, ·014 of a foot-candle.

* In shadow thrown by bonnet of lamp

Average of the 78 readings taken in this pit, ·0147 of a foot-candle.

Safety Lamp Pit D.

The following measurements were taken at the end of August Bank holidays, before the men had returned to work. The pit had been idle three days and there was no dust about. The face was the nearest to the main intake, and the lamp used was a new clean Patterson which gave the high reading of ·56 candle-power in the face. All the conditions were then very favourable, and the readings are high compared with those of pit C.

First stall in intake, coal 3 ft. thick with 4 to 6 inches of clod. Very little undercutting necessary. The coal is obtained by working out the butts of the slip, cleaning the top, and then taking the slip across in the usual way. The lamp was hung on a post 4½ ft. from the face and 22 in. high. The collier was supposed to be working over an area of coal 16 ft. in extent with the lamp midway. A second lamp was placed in the next stall in order to reproduce the normal conditions of work.

READINGS.

·0075	·0125	·005	·03	·035	·032	·03	·02	·015
·0075	·0125	·01	·025	·03 ×	·035	·02	·02	·015
·0075	·0125	·015	·025	·03	·03	·02	·02	·02
·0075	·0125	·015	·0275	·03	·02	·02	·02	·02

Average of 34 readings, ·0214 of a foot-candle.

Another Stall.—In this stall one end of the coal is freed and the coal is stripped across the face. Length of face worked by one man, $9\frac{1}{2}$ ft. Lamp $5\frac{3}{4}$ ft. from coal face. Candle-power of lamp, '44. Transverse fracture of coal seen throughout.

·025	·025	·025	·0175	·011
·03	·03 ×	·03	·012	·0125
·03	·03	·03	·012	
·025		·025	·014	·015

Average of 18 readings, '022 of a foot-candle.

In all readings it must be remembered that the illumination does not always depend on the distance from the lamp. In some cases the part nearest the lamp is in the shadow cast by one of the bars or by a post; while in measurements near the roof the bonnet of the lamp may cut off the light. There is also the angle at which the light falls on the face to be considered, and if the face slopes backwards a feebler illumination will be obtained.

A few measurements will now be given of the illumination present in places other than the coal face.

Collier ripping top, first rippings.

Width of road 8 ft. Coal 3 ft.; 4 ft. of top to be ripped down. Lamp $6\frac{1}{2}$ ft. from the middle of the area worked.

READINGS.

·03, ·03, ·02, ·025, ·015, ·01, ·01.

Average of the eight readings '0187 of a foot-candle.

Collier setting pair of $6\frac{1}{2}$ ft. timbers. Lamp on neck-strap.

Average illumination..... '04 foot-candle

Haulier spragging off in parting, lamp in hand.

Illumination on wheel '075 foot-candle

Shackling '06 foot-candle

Repairer with lamp on neck-strap, wedging top of cog in hole in roof.

Average '05 foot-candle

Timberman notching arm.

'035 foot-candle.

Roadman cutting bottom.

'025 foot-candle.

SURFACE BRIGHTNESS MEASUREMENTS.

The diffused reflecting power or albedo of any substance is obtained by measuring the amount of light reflected from its surface, and comparing the amount with that reflected from a standard white screen placed in the same position relative to the source of light. To measure the albedo of the coal a reading is taken of the amount of light reflected by the standard screen placed against the coal face, and a second reading is taken from the coal itself after the screen has been removed, care being taken to keep the lamp in the same place. The proportion which the light reflected by the coal bears to that reflected by the screen gives the albedo of the coal. I have preferred to state the results in terms of absorption. The readings of the surface brightness of the coal are so low that they are very difficult to obtain and should be taken as only approximately true. I have used a surface brightness attachment with a large field, and even with its help my readings are not always consistent. The readings, however, show clearly that the coal absorbs almost all the light which falls on its surface, and when the smallness of that amount is remembered it might almost be said that the coal face reflects no light. A few actual measurements will be given, and then the results of a large number of observations will be stated in general terms.

Coal.

Surface brightness on screen	·138
„ „ of dull coal slip	·011
Absorption by the coal, ·127, or 92 per cent.	

Surface brightness on screen	·2
„ „ of coal	·015
Absorption, ·185, or 92 per cent.	

Clift and Ironstone.

Surface brightness on screen	·245
„ „ of clift, white joint... ..	·06
Absorption, ·185, or 75 per cent.	

Surface brightness on screen	·1875
„ „ of ball of mine (iron-stone)	·04
Absorption, ·1475, or 78 per cent.	

Corresponding readings of a bituminous coal and a fireclay which lay underneath :—

Absorption by coal	97 per cent.
" " fireclay.....	83 "

Timber.

Surface brightness on screen	·85
" " post covered with	
coaldust	·085
Absorption, '765, or 90 per cent.	
Surface brightness on screen	·125
" " of whitewashed post	·0475
Absorption, '0775, or 50 per cent.	

ABSORPTION OF LIGHT BY THE COAL.

House Coal Colliery.

Damp fresh coal	94·5 per cent.
Dull coal slip.....	96·8 "

Staffordshire Colliery.

Freshly-fractured surface ... 93 to 96 per cent.

Midlands.

Bright coal.....	86 to 92 per cent.
Dull coal.....	88 " 96 "

South Wales.

House coal.....	Up to 97 per cent.
Steam coal.....	97 "
Anthracite.....	95 "

I have taken a few readings of the different ores :—

Quartz	73 per cent. absorbed
Gold quartz	77 "
Tin ore	80 "
Copper ore	80 "
Hæmatite.....	80 "

The Influence of Deficient Ventilation on the Candle-Power of the Safety Lamp.

It is a well-known fact that if you go from a return airway to a main intake the flame of the candle rises. I have taken some measurements in the various districts of different pits in order to determine the influence of bad air on the safety lamp. I tested the constancy of several lamps beforehand, and after several experiments found that a Patterson fireman's lamp with the lower air feed shut gave a practically constant reading for a period of

three hours. In the trial experiments readings were taken every five minutes for three hours, and in the intervals the lamp was swung about or carried from place to place. The lamp was irregular until it warmed up, but afterwards there was only a variation of .002 during the whole time. A large flame gives very irregular results, so in all the following readings a small flame was used to start with. I also experimented with a standard candle fixed in a safety lamp, but this also gave very irregular readings.

A.—HOUSE COAL PIT.

The pit was an old one and poorly ventilated. There were very few splits in the air current. At the time of my visit the barometer was low.

	Main intake.	Main return.	Last stall in return.	Main intake.
Safety lamp .....	.21*	.136	.085	.25
Standard candle ...	1.25†	.75—.77	.7	1.1
Time	12 noon	12.15	1 p.m.	1.30 p.m.

All measurements taken at one foot. * These first measurements were taken too soon after I had descended the pit, and are unreliable. † I could not keep the candle flame steady, but in the check reading was able to do so.

B.—WELL VENTILATED OPEN LIGHT COLLIERY.

		Relative readings.*
Main intake .....	.045	1.0
Main return .....	.0375	.8
Coal face .....	.0375	.8

* Main intake = 1.0.

C.—WELL VENTILATED SAFETY LAMP COLLIERY.

		Relative readings.
Main intake .....	.07	1.0
Main return .....	.055	.8
Coal face .....	.045	.64

D.—POORLY VENTILATED SAFETY LAMP COLLIERY.

		Relative readings.
Main intake	·06	1
Level with return air from one small district	·05	·8
Last stall in district	·025	·4
Midway intake and return	·05	·8
Main return	·04	·66
Main intake (two hours later).....	·065	1

All these measurements must only be taken as relative, as it is impossible to start always with the same candle-power lamp. The safety lamp was left untouched throughout.

E.—WELL VENTILATED NAKED LIGHT PIT.

		Relative readings.
Main intake	·05	1
Main return	045	·9
Coal face	·035	·7

F.—WELL VENTILATED STEAM COAL COLLIERY.

		Relative readings.
Main intake	·05	1
Main return	·05	1
Conveyor face (hot)	·035	·7*
Barry road (cool)	·048	·98

* Last place in district.

I have lately been assisting Dr. Haldane in a series of experiments upon the effects of a diminution of the oxygen supply on the illuminating power of the safety lamp, and our results have been published in the *Trans. Inst. M.E.*, 1912, vol. xliv., in a paper entitled "The Effects of Deficiency of Oxygen on the Light of a Safety Lamp." I must thank the Council of the Institution of Mining Engineers for permission to republish part of the paper here. (See Appendix.) I may say here that the experiments proved that the illuminating power of the lamp fell off rapidly as the oxygen percentage diminished.

Account of a Special Investigation in Two Midland Collieries.

Among some statistics which were kindly sent me from the Midlands the following figures appeared :—

	Men.	Nystagmus cases.
Safety lamp pit A	1,500	31
Naked light pit B	1,300	34

The other naked light pits in the district, not in the neighbourhood, contained four cases among 1,316 men, while the other safety pits contained 40 cases in 8,365 men. The figures given by pits A and B contradicted my views so strongly that I paid a special visit to them. I have been asked not to mention the pits by name. The two pits are within a mile or two of each other, and are worked under the same conditions apart from the question of lighting. The seams are about 5 ft. thick, and all the coal is got by bottom holing to a distance of between 5 and 6 feet. The men in the steam coal pit hole in a fully reclining position, but in the other pit a soft rock 6 to 8 inches thick lies under the coal in some districts and allows the holer room to assume a semi-reclining position. The coal is very hard and difficult to cut. The ventilation in both pits is good, and there is very little dust.

I found, as I expected, that a large amount of migration had taken place from the steam coal pit to the naked light pit. Out of 13 cases which I saw at the naked light pit, six had worked with lamps before.

(1) Deputy. Always uses safety lamp.

(2) Candles 20 years, he then worked in a safety lamp pit for five years, and on his return to the naked light pit had trouble with his eyes at once. He was able to work on for twelve months before failure.

(3) Safety lamps 30 years, candles 12.

(4) Candles 23 years, safety lamps 20 years.

(5) Lamps 11 years, candles 11 years.

(6) Lamps 10 years, candles 30 years.

The remaining seven men had worked with candles almost entirely. In a list, prepared at my request by the colliery clerk, of

21 cases of nystagmus at this pit, nine men had worked almost all their lives with safety lamps.

Of the men at the safety lamp pit only one man had worked any length of time with candles. This man failed within a year of starting with safety lamps.

Pit B is an old pit, and the mean age of the cases examined was 50·8 years ; in pit A the mean age was 44·8 years.

In pit B the candles were placed as far away from the coal as the safety lamps in pit A, and thus one of the great advantages of the candle over the safety lamp was lost. I took readings of the light falling on the coal face in both pits.

Average reading in pit A...	·022	foot-candle.
" " " B...	·056	"

Even in this case the light in B was two and a-half times the amount in A, but in other naked light pits in which I have taken readings the light was about five times that found in steam coal pits. In most naked light pits which I have visited the candles were placed much closer to the face than was the case in pit B. When a man holes to the extent of 5 or 6 feet as in these pits, he works in a confined space entirely surrounded by a black surface capable of absorbing 86 to 96 per cent. of all light falling upon it. In these conditions the light of the candle more nearly resembles that of a safety lamp, as all the light it gives in the upper segment of the field is absorbed by the overhanging coal which plays the part of the bonnet of the lamp. The result is that only the horizontal rays of the candle are utilised. I do not think anyone will regard $1/20$ (·056) of a foot-candle as a good light.

I found it much easier to detect nystagmus in the 17 cases I saw at the safety lamp pit than in the cases I saw at pit B. The average time between onset and failure in A was 13·7 months, and in B 25 months. In other words, the cases were more marked and failure occurred more quickly in the safety lamp pit. I attribute the number of cases at pit B chiefly to migration of men from the surrounding safety lamp pits ; to the age of the pit and of the men employed ; to the hard nature of the coal, making the work of holing very difficult ; to the frequency of nystagmus in the district generally ; and, finally, to the poor light obtained in the pit. This poor light is due to two factors, the distance the men place their candles from the face and to the great absorption of the light by the coal itself. The doctor in the neighbourhood told me that the

managers of the safety lamp pits around made a point of "unloading" all cases suffering from trouble with their eyes into this naked light pit.

THE SAFETY LAMP.

The safety lamp was introduced generally about 1850, and the first recorded case of nystagmus was described by Decondé in 1861. As Romiée points out, these dates have a very significant relation. Commencing with the Davy pattern, consisting of an oil reservoir and a gauze cylinder enclosing the flame, the safety lamp has passed through many modifications up to the present day. The three main parts are the oil reservoir, the glass cylinder surrounding the flame, and the gauze with its protecting metal bonnet. The modifications in later years have been the introduction of the double gauze, improvements in the arrangements for lighting and locking, and the use of a more volatile oil. The introduction of the Wolf naphtha lamp was a great step forward. Up to the present most attention has been paid to the safety of the lamp, its illuminating power being a secondary consideration. Lately, and especially since the £1,000 prize offer, the electric lamp has come to the front. The great difficulty of obtaining a reliable accumulator is being overcome, and, in my opinion, the modern oil safety lamp, except for the purposes of gas testing, will soon be as obsolete as the Davy.

The Mines Accident Commission gives the following table of the candle-power of the various lamps (6) :—

Davy.....	·12
Clanny	·68
Mueseler	·40 to ·70
Marsaut	·47

Prussian Firedamp Commission :—

Davy.....	·19
Clanny	·62
Mueseler	·69
Marsaut	·68

Romiée gives the following measurements of the lamps as used in the mine (90, p. 79) :—

Wolf	·87
Mueseler	·50
Marsaut	·37

Rutten (90, p. 96):—

Marsaut	·47
Mueseler	·50
Wolf	1·01

Very similar figures are given by Nieden and Dransart.

Snell gives the following table (106, p. 14):—

Standard candle.....	100
Tallow candles (16 to the pound)	69
" " (18 to the pound)	55

I have taken measurements of a large number of safety lamps, which were all carefully trimmed to give a constant flame such as would be used by the miner at his work. The measurements were all taken with the Trotter photometer, and the instrument was checked at each set of readings with a standard candle and the Rumford test.

COMPARATIVE READINGS.

	Photometer.	Rumford test.
Series A.....	·409	·40
B.....	·45	·44
C.....	·405	·40
D.....	·27	·26
E.....	·22	·22

LAMPS TESTED.

Number.	Kind.	Candle-power.
1	Cambrian fireman's (like a Davy).....	·165
	Cambrian (Thomas and Williams)—	
40	" old type	·235 to ·27
3	" newer type	·35
20	" latest type	·4
1	" (new lamp).....	·65
60	Ackroyd and Best.....	·4
80	Patterson	·42
1	Wolf	·8
2	Float primary electric lamp ..	·9
3	Pape electric lamp	·6

Some of the best lamps of each variety gave readings of ·6 to ·65 candle-power, but in these cases the flame was higher than

would be used in work, and in several cases the lamps soon began to smoke.

A series of tests was made of the lamps of all the collieries in a certain district. In all cases the clean and dirty lamps were examined, and every effort was made to obtain similar conditions. Six hundred and eighty lamps in all were examined, and 480 of these were trimmed by the manager, who assisted me in those tests. To obtain the averages given below, at least 20 lamps were examined in each case.

PIT A.

Steam coal colliery using an old pattern of Thomas and Williams Cambrian lamp. Lamps hand cleaned, glass and gauze not removed.

There were no proper brushes or cloths in the lamp room.

Clean lamps	·235 candle-power
Lamps after an eight-hour shift ...	·22 " "

Result of cleaning = 6·3 per cent. increase.

PIT B.

Steam coal colliery using an old pattern Thomas and Williams Cambrian lamp. Lamps are usually cleaned with machine brushes, but at the time of my visit, owing to a breakdown of the machine, they were hand cleaned.

Clean lamps	·27 candle-power
Lamps from a very dirty seam	·18 } ·2
" " clean place	·22 } " "

Cleaning = 26 per cent.

At this colliery some of the lamps were sent back by the men in a very dirty state, and no attempt had been made by them to clean the glass. One lamp gave a reading as low as ·11 candle-power.

PIT C.

Steam coal colliery using Ackroyd and Best's lamps. The lamps were old and some of them not well kept. Machine cleaned.

Clean lamps	·33 candle-power
Dirty lamps	·25 " "

Cleaning = 24 per cent.

PIT D.

Steam coal colliery using Ackroyd and Best lamps chiefly, some Patterson, and a few Cambrian lamps. The lamps were all very well kept and machine cleaned.

Clean lamps, Patterson	·43	candle-power
Cambrian	·4	„ „
Ackroyd and Best ...	·4	„ „
Dirty lamps	·28	„ „

Cleaning = 30 per cent.

At this colliery a series of tests was made of lamps coming from different districts of the pit and from different grades of workmen. In all cases lamps at the end of a shift were taken.

Colliers' lamps from a clean place:—

Ackroyd and Best.....	·28	candle-power
Patterson	·31	„ „
Cambrian (new lamps)	·32	„ „

Colliers' lamps from a narrow and dusty conveyor face:—

Ackroyd and Best.....	·24	candle-power
Patterson	·27	„ „

Night repairers' lamps:—

Ackroyd and Best.....	·26	candle-power
-----------------------	-----	--------------

Hauliers' lamps:—

Patterson	·31	candle-power
-----------------	-----	--------------

PIT E.

Steam coal colliery using Patterson's lamps entirely machine cleaned:—

Clean lamps	·42	candle-power
Dirty lamps	·27	„ „

Cleaning = 35·7 per cent.

In this colliery the lampman picked out the dirtiest lamps, and the readings are low on this account. In all the other cases the lamps were not selected except as coming from a certain district.

I have drawn up a table showing the number of men employed at each pit, the number of cases of nystagmus, and the average candle power of the clean and dirty lamps at each colliery.

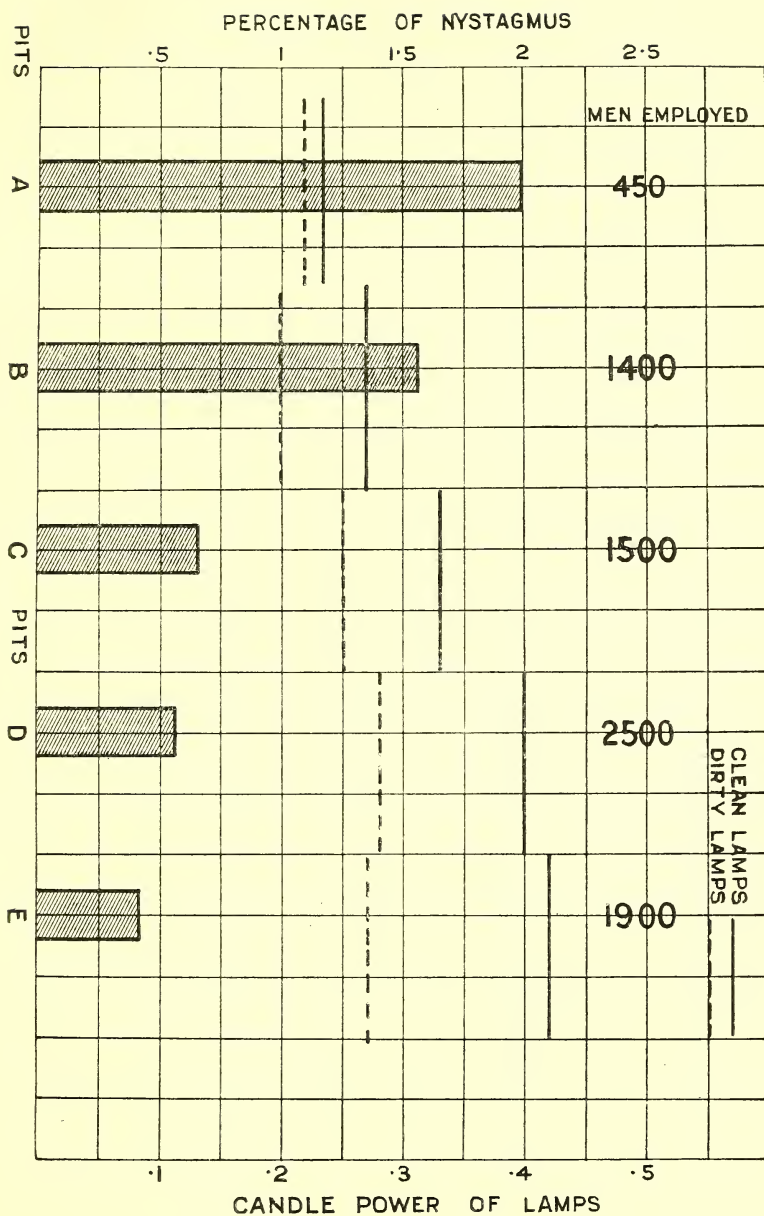


FIG. 29.

TABLE 24.

Pit.	Men.	Cases.	Per cent.	Candle-power, clean lamps.	Candle-power, dirty lamps.
A	450	9	2	·235	·22
B	1,400	22	1·57	·27	·2
C	1,500	10	·66	·33	·25
D	2,500	14	·56	·4	·28
E	1,900	8	·42	·42	·27

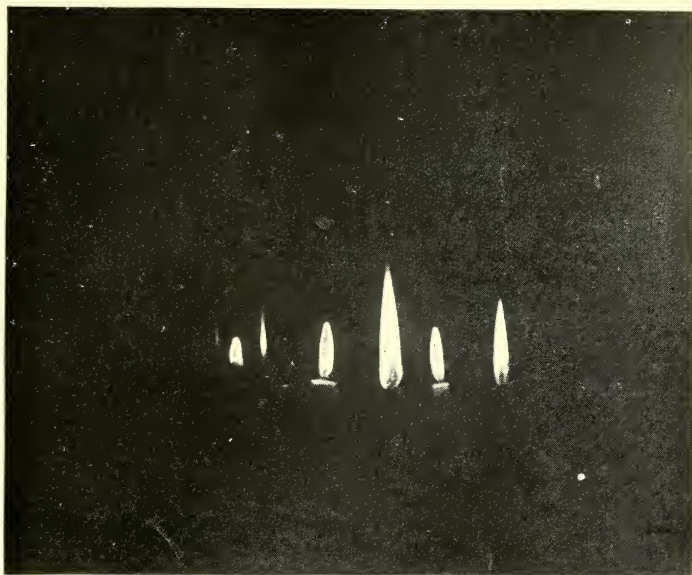
The five pits A—E are consecutive pits in the same valley. A is the highest in the valley—*i.e.*, nearest the outcrop—and consequently the oldest and least up to date in the matter of lamps and ventilation. Up to three years ago a sister colliery, which I will call A 1, was worked with A, both having the same upcast shaft. A 1, employing 377 men, was stopped, and most of the men were given employment in pits A and B. A certain number, however, made their way down the valley and obtained employment in pits C, D, and E, especially in the nearest pit, C. A and B belong to one company, C, D, and E to another, and there has been a steady flow of men from the two upper pits to the others for some time. The ventilation in the pits A and A 1 has been very poor, and the lamps used of low candle-power. I have traced 16 cases of nystagmus from pit A 1 to the lower pits; three cases are still latent, and the others are distributed as follow:—A 5, B 6, C 3. Six cases of nystagmus in pit C have come from the upper district.

THE SAFETY LAMP AND CANDLE COMPARED.

The differences between the light given by a candle and a safety lamp have already been referred to above, and I now propose to discuss them more fully. Perhaps the most important difference is the distance which they are placed from the coal face.

Distance from Coal Face.

The candle can always be placed nearer the coal face than the safety lamp, and in many cases is only 12 to 18 inches away. The lamp must by law be out of reach of the swing of any tool used, and



1 2 3 4 5

FIG. 30.—SIMULTANEOUS PHOTOGRAPH OF THE FLAMES OF—

(1) A modern safety lamp; (2) a standard candle; (3) a tallow candle with wick spread out; (4) a wax candle used in the open-light pits of South Wales; (5) a tallow candle with wick untouched. The reflection of the flame of the safety lamp from the lamp glass is seen between (1) and (2).



FIG. 31.—PHOTOGRAPH OF CANDLE AGAINST A WHITE BACKGROUND.

The candle is similar to those used in the naked light pits of South Wales. The white background is 21 in. square, and the edges are seen. In this and the following photographs the exposure, development, and printing were all performed under similar circumstances.

is often 6 or more feet away from the coal face. The candle can be placed anywhere very quickly, and if knocked over can be relighted. The safety lamp requires care, takes time to fix, and is generally placed on a post. There is a strong tendency to leave the lamp in the same position, even when a large area of coal face is worked. The candle is so easy to move that there is no reason for leaving it in the same place. For the benefit of my medical readers I may say that the candle is fixed by embedding it in a small ball of clay which will adhere to any place against which it is pressed, though some colliers use a small socket at the end of a spike which may be driven into a post or into the coal itself. I have also found that the lamps are moved more frequently in a narrow seam than in a thick seam, so the area worked from one given position of the lamp is smaller and the illumination better.

Candle-Power of the Safety Lamp and Candle.

The candle-power of the modern safety lamp is rarely more than $\cdot 5$, while the candle is usually at least 1 candle-power. The candle-power of several kinds of safety lamps is given on page 78, and these measurements were taken under the best conditions. In the coal face I have only once obtained a higher reading than $\cdot 36$ candle-power. One boy's lamp gave $\cdot 1$ candle-power, and he was working 8 ft. away from his lamp with the rays of light falling obliquely. The illumination present was $\cdot 001$ of a foot-candle.

When the illuminating power of the safety lamp and candle are compared, the total amount of light given by each should be taken into consideration, as well as the actual candle-power in the horizontal direction.

The total light given by any source of light can be measured in several ways, but one of the simplest is the method given on p. 152 of Trotter's *Illumination*.

Measurements are taken at several fixed angles, and the mean reading gives the mean spherical candle-power of the source of light in question, and may be taken as a measure of the amount of light given. I have measured the light given by a standard candle and a Patterson's safety lamp in this manner, and the relative figures obtained are given below :—

Patterson's miners' lamp.....	$\cdot 14$
Standard candle.....	$\cdot 635$

The total light then given by a standard candle is more than four and a-half times as much as that given by a modern safety lamp. A dirty lamp may only give half the amount of light of a clean one, so that at the end of a day's work the collier may be working in an illumination one-ninth of that given by a standard candle.

Candles used in Naked Light Mines.

I have taken several measurements of the candles used in the naked light mines of England and Wales. In my own district wax candles (16 to the pound) are used. These candles give a candle-power of 1.1. Tallow candles are used in Staffordshire. It is the custom of the miners working with tallow candles to spread the wick to obtain a large flame. I have in this manner been able to get a flame measuring 4 in. high and $\frac{6}{8}$ of an inch at the base. Trotter gives the ordinary candle flame as 2 in. by .4 in. When this large flame is obtained, a candle-power of 2 is present, and the tallow candle may be said to give an illumination of from 1 to 2 candle-power.

Tallow candles obtained from Somersetshire gave readings varying from 1.3 to 2 candle-power. Wax candles are used there, and these gave 1 candle-power. The candles used in the Forest of Dean give 1 candle-power. In the main roads the men use small oil lamps of 2 candle-power, while the hauliers use a larger lamp giving 4 to 5 candle-power.

Constancy.

The wax candle remains constant all day, but the tallow candle requires frequent attention. If carefully trimmed, the tallow candle will give a light varying from 1.3 to 2 candle-power, but if the wick is allowed to get crusted, the illumination falls to half a candle-power. Young men and boys should always use wax candles, but careful men might get better results with the tallow variety. The safety lamp is not constant, the figures I have given show that the lamps may lose 36 per cent. of their illuminating power at the end of a shift, when an average of a large number of lamps is taken. If, however, individual lamps are examined, it will be found that in several cases a dirty lamp will only give one-quarter of the candle-power of a clean lamp. One lamp I examined gave only .065 of a candle-power. It was quite impossible to obtain

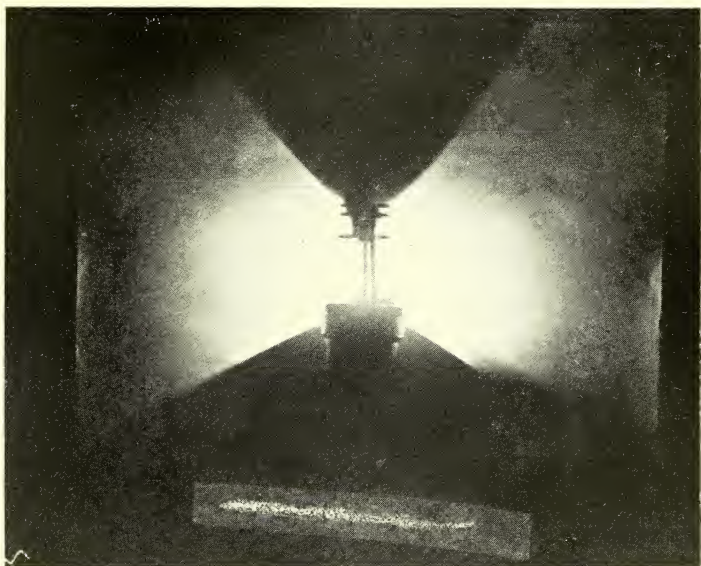


FIG. 32.—A PAPE ELECTRIC LAMP.

Edges of the white background well seen, but the light in the lower part of the field is much inferior to that of the candle.

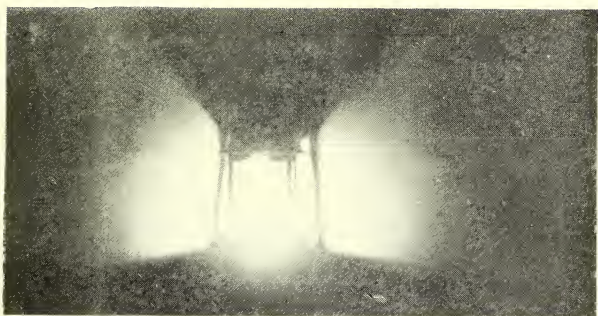


FIG. 33.—CLEAN PATTERSON LAMP.

The edges of the background are faintly seen. Note the extent of the shadows.

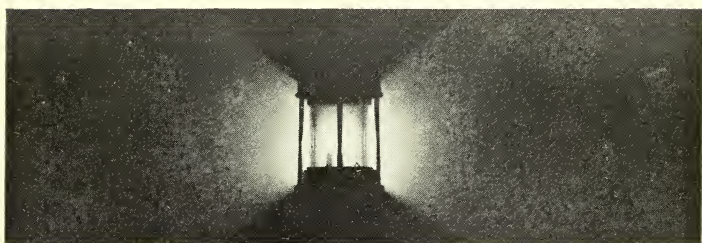


FIG. 34.—PATTERSON LAMP AFTER AN EIGHT-HOUR SHIFT.

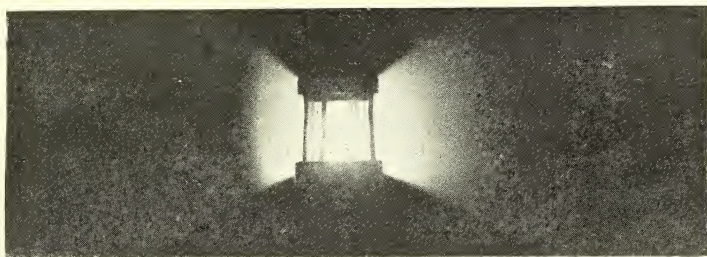


FIG. 35.—PHOTOGRAPH OF AN ACKROYD AND BEST LAMP TAKEN
AFTER AN EIGHT-HOUR SHIFT.

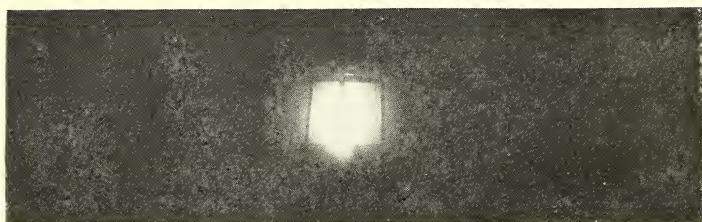


FIG. 36.—PHOTOGRAPH OF THE SAME LAMP AS IN FIG. 35 TAKEN
WITHIN A FEW MINUTES OF THE LAST.

The lamp has been placed in a black box the same distance away from the camera as before. Exposure, development and printing were all carried out under exactly similar conditions. Note the effect of absorption of light by the black surface. This absorption occurs underground.

COAL FACE

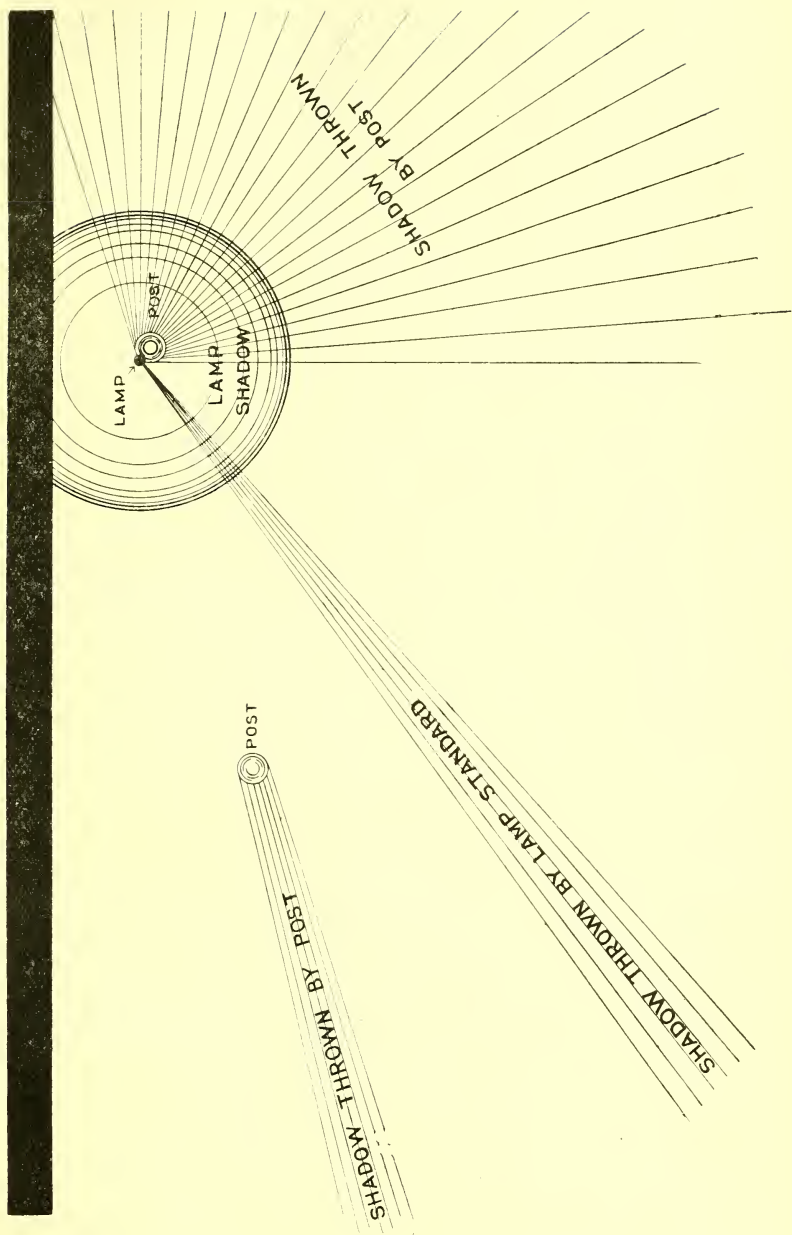


Fig. 37.

COAL FACE

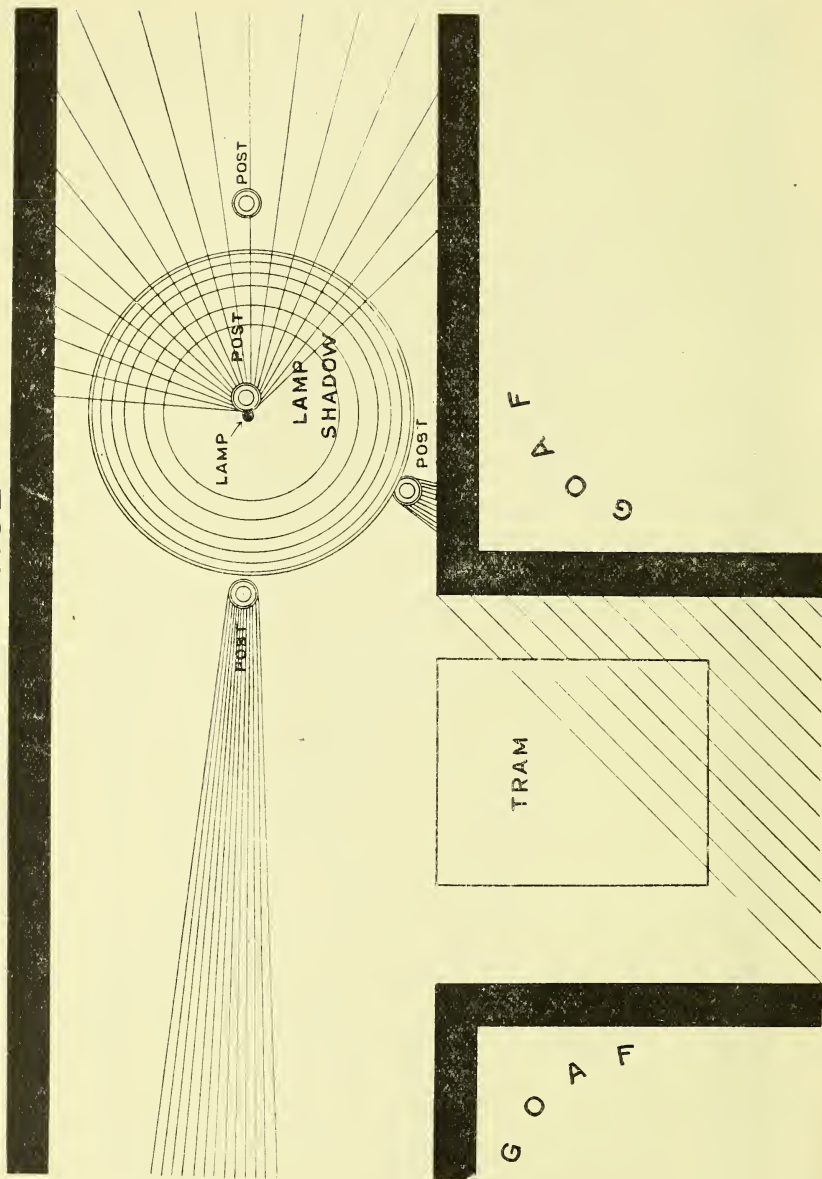


FIG. 38.

a bigger flame, as the wick had been allowed to char badly, and the pricker refused to act. Another lamp gave '14 candle-power, it had been smothered. Another lamp with oil over the glass gave '13 candle-power. A fourth lamp, which was noted as very dirty, gave '12 candle power. The effect of a bad ventilation is more marked on the lamp than on the candle. I have taken measurements of a lamp and candle in the main intake and again in the last stall in the return. The candle lost 36 per cent. and the lamp 66 per cent. of their illuminating power.

Shadows.

I have taken measurements of the shadow cast by the bonnet and oil reservoir of several kinds of safety lamp by hanging the lamp against a white background which has been accurately graduated into degrees, the flame of the lamp coinciding with the centre of the circle. *See* figs. 32-36. The readings are given below :—

TABLE 25.

Patterson's fireman's lamp	170 degrees of light
„ miner's lamp	180 „ „
Protector	170 „ „
Ackroyd and Best.....	160 „ „
Cambrian	180 „ „
Pape electric lamp	190 „ „
Float electric lamp (primary type)	160 „ „
Candle.....	350 „ „

Diagrams of measurements in the mine are also shown (figs. 37, 38).

Relighting.

Safety lamps often go out through careless handling, and the man is left in the dark. If this happens in the early hours of the shift the man has to walk back to a relighting station and lose half an-hour or more. If, on the other hand, the lamp goes out an hour or so before finishing time the man will not go back, but will work with the help of his boy's lamp, thus making one lamp serve for two people. I have seen five men working with two lamps between them. The man at the end of his shift would feel the effect of this want of light more than at any other time.

It has also been shown by several observers (Messrs. Butterfield, Haldane and Trotter, and by Mr. Paterson) that there is a reduction of 6·25 to 6·6 per cent. in the illuminating power of the Harcourt

lamp with each increase of 1 per cent. of the aqueous vapour of the air. This would apply equally to the safety lamp, and as the safety lamp pits are always much hotter, and contain more aqueous vapour than the naked light pits, this is another cause of the poorer illumination in safety light pits. Three interesting readings of the same lamp in this connection will be given :—

Lamp in main intake	·05
„ conveyor face (hot)	·035
„ Barry road (cool)	·048

The lamp was untouched throughout.

Taking all these factors into consideration, we may say that the collier in a naked light pit works in an illumination five to 10 times as great as that obtaining in a safety lamp mine.

CHAPTER VI.

The Personal Factor in the Disease.

OBSERVATIONS ON PIGMENTATION.

I NOTICED that several of my severe cases had blue eyes and fair hair. The possibility of lack of pigment being one of the predisposing causes of the disease suggested itself to me, and I took notes of all my cases.

Nettleship (62), in his Bowman lecture, and in the *Transactions of the Ophthalmological Society* (63), suggests that congenital nystagmus may be due to a partial albinism confined to the eyes. My own series of cases undoubtedly shows a marked preponderance among the fair. The figures are too small to draw any definite conclusions, but they are certainly suggestive.

TABLE 26.—SHOWING COLOUR OF HAIR AND EYES IN NYSTAGMIC CASES. With each colour eye three sets of figures are given; the first refers to fair, the second to medium, and the third to dark-haired people.

Blue eyes...	101, 97, 70, eyes only noted 15	Total, 283	} 387, or 65·16 per cent. } 207, or 34·84 per cent.
Blue - grey and grey	21, 45, 37, „ „ „ 1	„ 104	
Light brown	8, 24, 23	„ 55	
Dark brown	4, 60, 81, eyes only noted 7	„ 152	

In six cases the colour of hair and eyes was not noted.

TABLE 27.—CONTROL TEST. Adult miners from the same district.

Blue	59, 76, 57	Total, 192	} 272, or 41·97 per cent.
Blue-grey and grey...	13, 17, 50	„ 80	
Light brown	5, 70, 43	„ 118	} 376, or 58·03 per cent.
Dark brown	5, 53, 200	„ 258	

TABLE 28.—COLOUR OF HAIR.

	Nystagmus.	Control.
Fair	134 } 360, or 63 per cent.	82 } 298, or 46 per cent.
Medium	226 }	216 }
Dark.....	211 or 37 per cent.	350 or 54 per cent.

Wilde (Dublin), quoted by Pearson (126), gives the following table as result of examination of 2,776 persons. The Irish are held to be a fair-eyed race, and the predominance of light-coloured eyes is marked.

Blue.....	752
Grey	1,132
Hazel	288
Dark	604

THE HEREDITARY FACTOR IN MINERS' NYSTAGMUS.

The possibility of an hereditary factor in nystagmus has been noted by some authors. Snell writes (106, p. 7):—"A tendency almost appears to prevail in some families to the development of nystagmus. Thus, three brothers working in a candle-lighted pit were sufferers; two brothers at least twice have been met with, and a father and son more than once."

At the Oxford Ophthalmological Congress, Mr. J. Jamieson Evans (43) said:—"Several of my cases occur in families." I will quote an extract from the letter of a colliery manager:—"Two brothers affected, so it would seem to be a family weakness. Their father, moreover, 'played' several times on account of his eyes, but whether he had nystagmus or no I could not say."

I have taken notes of my own cases, and have found relationship in 12 cases out of 600. In some of the older colliery districts in Wales intermarriage of near relatives is common. I know one such district very well, and six of my 12 cases come from this district. Nystagmus attacks such a large percentage of the working population that you would expect to find a certain number of cases among relatives. I do not think myself that this proportion is in excess. If the hereditary factor has any influence it probably acts through the transmission of ocular defects.

Notes of Cases.

From one district, where nystagmus is common and inter-marriage frequent,

Cases 72 and 79 are brothers.

Cases 54 and 114 are father and son.

Case 356 has a brother affected.

Case 183. Father and six sons working underground, father and two sons affected.

Cases 332, 333 are brothers. Father and two other brothers working underground are not affected.

Cases 384, 385 are uncle and nephew.

Cases 9A, 11A are father and son.

OCULAR DEFECTS.

Ocular defects resulting from the presence of error of refraction, or from disease of or old injury to the eyes, may act as predisposing causes to the onset of nystagmus. In the past the personal factor has been too much neglected. Some men are able to spend a lifetime underground without ill effects, while others may develop the disease in less than six months. I have examined men who have worked 60 years in a pit without showing any sign of nystagmus. Why should men working under precisely similar circumstances suffer unequally? Is it because some men are unable to stand the strain of the pace at which the modern mine is worked, or is there some personal physical defect?

Norman (66):—"It is well known that, of the miners working under almost identical conditions in a certain seam, only a certain percentage develop nystagmus." This suggests that there is a personal factor to be reckoned with that determines the onset of the disease. The disease has been shown to attack those men who use their eyes the most in a much larger proportion than the other workers. I believe that acuity of vision is rarely normal in any man who has spent many years underground. During an examination of underground officials the 6/6 line of the test type was read with considerable hesitation, even by many men who had no sign of nystagmus. My own figures show that the acuity of vision is markedly diminished in cases of nystagmus. This is quite contrary to the generally accepted view, which is that, in the absence of movement, vision is little or not at all affected. My own

tests were carried out in the absence of any apparent movement, and whenever the men complained that their eyes were in motion the test was stopped. I have often been struck with the limited vision which is present in the acute stages of the disease, and it is interesting to watch the gradual improvement as the nystagmus becomes less marked. The amount of acuity of vision may be taken as a measure of the severity of the attack, and the improvement as a reliable sign of the progress of the recovery from the disease.

TABLE 29.—SHOWING ACUITY OF VISION.

Too bad to test	31
Not examined	70
Normal	64
6/9	89
6/12	91
6/18	92
6/24	61
6/36	58
Less than 6/36	44

The more important question of error of refraction as a predisposing cause has also been a matter of contention. Nieden (65, p. 141) places defects of sight as the second cause in the production of the strain necessary to produce the disease. Romiée (29) says that cases are rarely emmetropic; most are hypermetropic, often to a marked degree. Thompson (115) says we rarely find nystagmus in the emmetropic eye, and quotes the late Dr. Brown, of Tredegar, who had over 40 years' experience in a colliery practice, as saying that the majority of cases were hypermetropic. Mr. D. Leighton Davies kindly sent me notes of 14 cases, in five of which no note of refraction was taken, in the remaining nine cases seven were ametropic. Snell, although nine of his 127 cases showed marked error of refraction, says that error of refraction is of no importance in the production of the disease. Dransart (29) says that 90 per cent. are emmetropic. Elworthy (41) thinks error may be a cause in young people. Norman (66), as result of examination of 200 cases, found error of refraction is upwards of 90 per cent.

Mr. S. McMurray, of Stoke-upon-Trent, has very kindly given me access to his figures, and permission to publish the results of his examinations for refractive error in cases of nystagmus. I quote his letter :—

“NYSTAGMUS 136.

Hypermetropic astigmatism.....	123
Myopic and mixed astigmatism	11
Emmetropia (less than +.75D)	2

It is true that a number of my cases had a small degree of astigmatism (+.5D), but in my experience the effect of correcting glasses was almost as well marked in these cases of small error as in the cases of larger errors.”

Brown and Mackenzie, in the *British Medical Journal* of October 5, 1912, p. 837, state that error of refraction was present in 90 per cent. of their cases of miners' nystagmus :—

Astigmatism	48 per cent.
Hypermetropia	27 „
Myopia	15 „

At the Oxford Ophthalmological Congress, 1912, J. Harrison Butler said 45 per cent. of his cases had error of refraction, and Folker (44) gave 75 per cent.

It may be said that most other authors think error of refraction of no importance in the production of the disease. My own figures are incomplete, but they show that a very large proportion of men suffer from refractive error. It was impossible to examine every case—sometimes because the nystagmus was too severe, at other times through lack of opportunity. As it was important not to call the attention of the latent cases to the fact that they had nystagmus, these were not examined. Owing to the presence of movement of the eyes and intolerance of a bright light, retinoscopy is only possible in a limited number of cases. This difficulty, and the *ex cathedra* statements of authorities like Snell and Dransart, have led in the past to the assumption that error of refraction has nothing to do with nystagmus. My method has been to employ the subjective test recommended by Hartridge (48) in his book on *Refraction of the Eye*. This method is much more liable to error than the objective retinoscopy test, but I have checked it whenever possible by retinoscopy. The large proportion of ametropia (83 per cent.) present in the cases examined, as shown by the tables, raises the question of the normal proportion of emmetropia in the general public. The best figures are published in Parson's *Pathology of the Eye*, vol. iii., p. 931 (76). A table is shown compiled from the work of Herrnheiser, who examined 11,000 eyes, and from the examination of 12,331 patients by Hertel. From the age of 10

onwards emmetropia, or normal vision, is found in 30 per cent. of all cases, hypermetropia in 50 to 55 per cent., and myopia in 10 to 15 per cent. Randall, in an examination of 200,000 eyes, confirms these results. Steiger (p. 936 *ibid.*) says that there is an astigmatism of from .5 to 1.0 D in two-thirds of all eyes. This large number of cases effected in the general public reduces the importance of my figures. They should now read 83 per cent. less 70 per cent. = 13 per cent. In other words, the percentage of refractive error in nystagmus cases is 13 per cent. greater than in the general public.

TABLE 30.—SHOWING ERROR OF REFRACTION.

Not examined }	125
Latent }	
Too bad to test.....	35
	<hr/>
	165
Normal	73 (16.79 per cent.)
Error	362 (83.21 per cent.)

This table shows that out of 435 cases examined, over 83 per cent. had error of refraction. In a previous communication (56) I stated error of refraction to be present in over 93 per cent. I did not in that paper include the latent cases among the firemen, whom I had been able to examine for error. In the present table I have included all cases I have been able to examine, and the percentage has fallen 10 per cent. In other words, error of refraction is less common in latent than in manifest cases, a condition you would expect to find, assuming a connection between the incidence of error of refraction and the onset of nystagmus.

TABLE 31.—SHOWING KIND OF ERROR IN THE ABOVE 362 CASES.

Hypermetropia	146 or 40.3 per cent.
Myopia	50 or 13.8 per cent.
Astigmatism—	
Hypermetropic	127
Myopic	36
Mixed	3
	} 166 or 45.9 per cent.

This table shows the kind of error present, and if the three cases of mixed astigmatism are left out, hypermetropia and hypermetropic astigmatism were found in 273 out of 359 cases, or in 76 per cent., while myopia and myopic astigmatism were responsible for the remaining 24 per cent.

TABLE 32.—SHOWING DEGREE OF ERROR.

Less than 1 Diopter	150 (chiefly astigmatic)
1 to 2 D	146
2 to 3 D	40
3 to 4 D	14
4D and over	12

This table shows the degree of error found. In 150 cases the error was less than 1D, and these cases were chiefly cases of hypermetropic astigmatism. The cases of high refractive error were chiefly myopic.

Illustrative Cases.

See cases 276, 294, 295, 433 and 441 on p. 105.

Case (4) Timberman, age 44. V with glasses 6/9, without 1/60.

$$\begin{array}{cc} \text{Rt.} & \begin{array}{c} - 3 \\ \text{---} \\ | \\ \text{---} \end{array} - 2.5 & \text{Lt.} & \begin{array}{c} - 1.5 \\ \text{---} \\ | \\ \text{---} \end{array} - 3. \end{array}$$

This man has failed three times. He suffered from marked headache and giddiness, both of which were relieved by glasses. The nystagmus, however, persisted for months, and he finally took up a post outside.

Case (7) Collier, age 30, underground 14 years. Alcoholic and great smoker. Marked headache and giddiness, which were relieved by glasses. The nystagmus persisted for several months.

$$\begin{array}{cc} \text{Rt.} & \begin{array}{c} - 1.5 \\ \text{---} \\ | \\ \text{---} \end{array} - 0.5 & \text{Lt.} & \begin{array}{c} - 2.5 \\ \text{---} \\ | \\ \text{---} \end{array} - 0.5. \end{array}$$

Case (14) Collier 39, underground 27 years, second attack. Has been working in narrow seams in a badly ventilated mine (lamps). He had bad headache, giddiness, nictitation, and head tremor. After stooping he would become quite blind. There was marked rotatory nystagmus present even below the horizontal.

$$\begin{array}{cc} \text{Rt.} & \begin{array}{c} - 2.25 \\ \text{---} \\ | \\ \text{---} \end{array} - 0 & \text{Lt.} & \begin{array}{c} - 2.25 \\ \text{---} \\ | \\ \text{---} \end{array} - 0. \end{array}$$

Case (22) Collier, age 42, underground 30 years. Error

$$\begin{array}{cc} \text{Rt.} & \begin{array}{c} - 5 \\ \text{---} \\ | \\ \text{---} \end{array} - 3.5 & \text{Lt.} & \begin{array}{c} - 5 \\ \text{---} \\ | \\ \text{---} \end{array} - 2.5. \end{array}$$

Idle six months, surface work 12 months, now at work underground again.

Case (50) Collier. Latent case.

$$\begin{array}{cc} \text{Rt.} & \begin{array}{c} - 2.5 \\ \text{---} \\ | \\ \text{---} \end{array} - 1.5 & \text{Lt.} & \begin{array}{c} - 3 \\ \text{---} \\ | \\ \text{---} \end{array} - 3.5. \end{array}$$

A slight latent convergence has been shown in the few cases I have tested with the Maddox rod. Many cases showed marked convergence, and I have notes of 15 cases in which the symptom was marked. Two cases told me that the squint had only come on after the onset of the nystagmus.

If asked to fix any point, the patient is at first able to do so, but he soon has to turn away or cover his eyes with his hands. In the same way they easily tire, and a man may only be able to read the newspaper for five minutes at a time. There is, besides, weakness of adaptation, which partly accounts for the discomfort felt by a patient when he enters a well lit room after dark. Weekers (124) has even gone so far as to say that failure of adaptation to light is the cause of nystagmus. *See p. 32.*

Olm (75) quotes three cases of miners' nystagmus with spasm of accommodation. Error of refraction was present in all.

Congestion of the conjunctiva with a general redness of the eyes is often seen.

The Relation of Old Injury to the Eye to the Onset of Nystagmus.

Very brief extracts from my notes on the most marked cases will be given. In most of these cases the man can be considered as one-eyed, the amount of vision in the affected eye being negligible.

(15) Collier, age 52. Left eye blind from birth. Globe at present very shrunken, with conical opaque cornea. The nystagmus is equally marked in both eyes. This man also shows a sign often present in bad cases. He can only fix an object when his eyes are in an extreme lateral position, and to maintain this position when walking about he has to sidle along.

(47) Collier, 50 years. A latent case. Cataract after an accident seven years ago.

(204) Ripper, age 27, perforating wound of right eye leading to traumatic cataract.

(155) Corneal opacity of right eye due to lime. V = less than 1/60. Working on surface last eight years.

(257) Opacity of left eye result of an old accident.

(273) Right eye lost many years before.

(316) Left eye lost 14 years ago.

(99) Old accident leading to opacity of the cornea. V = fingers.

(416) Penetrating wound of the right eye. Iridectomy performed in boyhood. V = fingers.

(590) Fireman, age 30, 16 years underground. Cataract left eye, result of accident.

The Relation of Old Disease of the Eye to the Onset of Nystagmus.

In two of my cases the onset of nystagmus has been hastened by an attack of iritis.

(21) In this case temporary nystagmus followed an attack of acute iritis in the right eye; there was evidence of old iritis in the left eye also.

(292) Nystagmus here followed an attack of double iritis at the age of 59.

Old corneal opacities are often present, and may hasten the onset of the disease.

(55) Haulier, age 45, corneal ulcers following an attack of measles in childhood. In this case the pupils are half occluded. "I only get trouble with my eyes when I am excited."

In cases (181, 415, 440, 260, 444 and 523), corneal opacities were present unknown to the patients.

Cataract.

I have seen so many cases of nystagmus following a commencing cataract, that I think there is a distinct connection between the two. In six cases (93, 123, 131, 288, 428 and 514), there was cataract in one eye, either commencing or well marked. *See also cases 47 and 204 above.* In three cases cataract was present in both eyes.

(130) Cataract in the right eye five years ago, now starting in the left eye. "I was all right till my left eye began to go."

Other cases will be quoted, *see p. 106.*

THE RELATION OF ACCIDENT TO THE ONSET OF NYSTAGMUS.

I am firmly convinced that accident determines the onset of the disease in many cases, probably by converting a latent attack into a manifest one. The extra strain thrown on a patient by the shock following an accident is just enough to upset the condition of unstable equilibrium which is present in the centres governing the associated movements of the eyes. In the same way I have noticed that nystagmus often comes on during convalescence from an accident, and I think this is sometimes due not to the accident itself, but to the fact that the man when at work has been able to overcome the tendency to the disease. He is, to use a cricketering

analogy, thoroughly set like a batsman after he has played himself in, and the enforced idleness caused by the accident has the same effect as the lunch interval, which is so frequently followed by the downfall of the batsman. This opinion has been confirmed by the number of cases who broke down following resumption of work after the big strike of 1912; the six weeks' enforced holiday had thrown them out of gear. In my own series there was a distinct connection between the onset of the disease and an accident in 94 cases. Dransart (35) calls particular notice to the frequency with which nystagmus follows injuries to the cornea, and quotes Razemon and Thevenon in support. In a later communication (37) he states that out of 90 cases in 1908, 21 had injury to the cornea, and 18 out of 110 cases in 1909.

Injuries to the Eyes.

Thirty-six cases sustained an injury to the eyes, which in many cases was only slight; a few cases will be quoted.

In 13 cases a slight injury to the eyes was followed immediately by symptoms of nystagmus. (36, 37, 256, 80, 137, 179, 271, 258, 488, 478, 507, 514, 534).

Case (137) A collier, age 54, underground 41 years. While holing in the coal he struck a small pocket of dust, which "exploded" in his eyes. "My eyes got bad at once, and I had to be led out of the pit. I had no trouble before."

In the second group of cases a slight injury was followed by an increase in the symptoms, which soon led to failure in work. This group comprises 11 cases (171, 224, 479, 418, 387, 363, 467, 455, 418, 308, 378).

Case (22) Three trivial injuries to the eyes which became worse after each accident, failure resulting.

ABRASION OF THE CORNEA.

Case (54) Haulier, 46, underground 32 years. Struck with a bar-hook in the left eye. Marked conjunctivitis with corneal abrasion. "Eyes quite good before, but now I cannot see at night." Well marked nystagmus.

Case (187) Collier 48, underground 34 years. Blow on left eye leading to opacity of the cornea, V = fingers only. Symptoms came on suddenly one month after accident.

Case (188) Collier 50, underground 31 years. Blow on eye leading to corneal abrasion, onset of symptoms at once; no work since.

Case (256) Collier 46, underground 35 years. Blow on left eye leading to pus in the anterior chamber. Nystagmus developed at once. No previous symptoms. V = fingers.

Case (254) Collier 45, underground 25 years. Septic corneal wound followed at once by symptoms.

Case (415) Collier Opacities of both eyes, but no distinct connection with onset of nystagmus.

SEVERE INJURIES TO THE EYES.

Case (17) Penetrating wound of the left eye, leading to complete loss of sight. No symptoms before. "After the accident I noticed I could not see so well with the good eye, and that the lamps were going round." Nystagmus marked.

Case (113) Collier, age 40 years. Penetrating wound of left eye with loss of sight. Marked nystagmus. No trouble before.

Case (310) Collier 18, underground 5 years. Lost right eye as result of accident, "trouble with eyes ever since."

Case (445) Collier, 49, underground 30 years. Blow on right eye with stone. Anterior staphyloma with opaque cornea. Both eyes affected. Nystagmus developed one month after accident.

In two cases (226, 455) nystagmus followed slight detachment of the retina.

INJURIES TO THE HEAD.

Injury to the head is frequently followed by nystagmus, in my series in 35 cases.

I have divided my cases into groups.

Cases in which nystagmus followed at once on a slight head injury:—

Case (1) A slight blow on the head on August 26 kept the man idle until August 30. On return to work he failed at once and had to be led out of the pit. (*See* p. 4).

Case (82) Timberman, age 47. A slight blow on the head was followed within 14 days by nystagmus.

Similar cases (93, 241, 244, 266, 306, 360).

Cases in which a slight head injury accelerated the onset of the nystagmus:—(69, 71, 203, 234, 318, 344, 353, 392, 400, 385, 472, 532).

Case (71) Haulier, age 42. "My eyes were bad before the accident, but became so much worse afterwards that I had to give up work."

Case (385) Collier, age 40, underground 25 years. Blow on head which kept him idle three weeks. On his return to work he found he was unable to do anything, and failed. His eyes were bad two years ago, but he had never lost any time.

SEVERE INJURIES TO THE HEAD.

Case (214) Collier, age 35, underground 25 years. Buried under a fall, general injuries to head and body with marked shock. He remained idle one year, and on his return to work found his eyes affected. No previous trouble.

Case (66) Collier, age 62, underground 50 years. Severe injury to head, which kept him idle one year. Has had trouble with his eyes since accident.

Case (39) Haulier, age 34, underground 20 years. As a result of a kick by a horse he had fracture of the nasal bones, followed by empyema of the frontal sinus. Nystagmus developed after accident.

Case (190) Collier, age 59, underground 40 years. Buried under a fall, severe injuries to head and fractured clavicle. Onset at once, the man becoming almost blind.

Cases (267, 277, 288, 345, 405, 407), all had severe scalp wounds, followed at once by nystagmus.

In four cases fracture of the skull was followed by nystagmus:—

Case (105) Repairer, age 40, underground 20 years. As a result of a fall of roof he sustained a fracture of the base of his skull. The eyes were quite sound before the accident, but became bad within four weeks. He complained of marked giddiness and headache. He resumed work and failed at once owing to the trouble with the lamps, "which were going round and round." In this case it was very difficult to detect any nystagmus, but marked tremor of the head was present.

Case (106) Collier, 25, underground 11 years. This man fell off a scaffold, 15 ft. high, on his head. He sustained very extensive scalp wounds and a fracture of the skull. (*See* p. 5).

Case (107) Collier, 54, underground 40 years. Lost right eye 30 years ago as a result of an accident. Five years ago he had a compound depressed fracture of his skull. Ever since this time he has had trouble in his remaining eye. "The lamps used to dance." Lately he has given up underground work and the nystagmus is no longer present.

Case (270) Collier, age 34, underground 21 years. On August 10 a fall of coal struck him down. He sustained a large scalp wound, and hæmorrhage from the nose and mouth followed. There was, besides, proptosis of one eye and hæmorrhage into the orbit on that side. He made rapid recovery and tried to resume work on September 11. He failed at once owing to headache, giddiness, and trouble with his eyes. On September 20 there was marked nystagmus present. I had not noticed any movement on previous examinations. He soon recovered completely and is now back at his own work.

Nystagmus following General Injuries.

Injury to the back is frequently followed by the onset of nystagmus. The symptoms come on during convalescence or immediately the man returns to work. In 23 of my cases a general injury was followed by the onset of the disease.

General shock was responsible for one case (6) (*see* p. 7), while in 14 cases the injury was to the back.

INJURY TO BACK.

Case (14) Collier, 22, underground 8 months. On September 20 he strained his back, and on October 11 his sight failed suddenly through the onset of nystagmus.

Case (26) Collier. Fall of roof injuring back. Onset three weeks after accident, no previous symptoms.

Case (28) was exactly similar.

Case (38) Collier struck by tram in back. Onset immediately on return to work.

Case (65) Collier, 36, underground 25 years. Severe injury to back. "Ever since accident my eyes have been going round and I have been unable to work.

GENERAL INJURIES.

Case (351) Collier, age 50, underground 37 years. This man cut his radial artery and bled profusely. Nystagmus developed within a few weeks, and the man, when I saw him, had been idle over 12 months.

Case (468) Onsetter 27, underground 14 years. Onset after amputation of the finger. No trouble before. This case is very interesting; his doctor told him that he had nystagmus and that he was able to claim compensation. The man, who had never had any trouble before, developed subjective symptoms as a result of his knowledge. Suggestion in a latent case of nystagmus is fatal.

Case (472) Broken leg and injury to head, followed in convalescence by nystagmus.

THE RELATIONSHIP OF ACCIDENT TO NYSTAGMUS.

The danger of a catastrophe from failure of a nystagmic fireman to detect gas has been alluded to on p. 23. I believe that a number of accidents are due to nystagmus, but it is of course very difficult to prove that any specific accident is due to the disease. The large number of accidents followed by the discovery of nystagmus, makes it necessary to ask the question whether the accident after all was not the cause but the effect of the disease. In one of my cases a broken arm resulted from the nystagmus, the man could not see where he was going and was knocked over by a tram. Several cases have been stopped by the manager, owing to the risk of accident. Strangely enough, the chief danger appears to be in the main roads, the collier being better able to look after himself in the face. It is also probable that many accidents at the face are due to the defective sight which the complaint produces. Rutten (95) lays great stress on the feeble illumination and the deficient sight of the collier as a cause of many accidents.

CHAPTER VII.

Diagnosis and Prognosis.

DIAGNOSIS.

DIAGNOSIS is made by noting the presence of a rotatory movement of the eyeballs. In most cases the diagnosis is easy, and there is no doubt about the presence of the disease. The following routine method should be employed. The patient should be asked to fix a pencil held about 12 in. in front of and on a level with his eyes. If movement of the eyes does not appear gradually elevate the pencil, asking the patient to follow it with his eyes only, the head being kept level. Note the degree above the horizontal at which movement begins; this gives a rough test of the severity of the disease. If this fails, ask the patient to stoop quickly, and examine the eyes as soon as he returns to the horizontal position. The test may be varied by holding a mirror underneath the patient's head and observing the eyes while the man remains stooping. Before a negative opinion is given the tests should be repeated in a dark room, and the following extra test applied. Focus a pencil of light at the junction of the cornea and sclerotic in a dark room; any movement of the eyes will then be readily seen. The rotation test advised by Reid (83), in which the man is spun round and round, should not be used, as Barany (3) has shown that nystagmus is produced in normal people in this manner. I have not found the ophthalmoscope of any assistance, but its use has been recommended by others. If, when asked to look up, the patient persists in raising his head and not his eyes, nystagmus is probably present. In these cases the test should be varied in this manner—one hand should be placed on the man's head to keep it flexed, the pencil should be held in the other hand, and the test continued as before. This method brings out the movements and any head tremor that may be present. At the same time a sense of great resistance on



FIG. 39.—THE HEAD TEST.

This is one of the best methods of bringing out the movements of the eyes and the tremor of the head so often present in nystagmus. The patient's head is kept strongly flexed with one hand and his attention is directed to the other hand held above his head.

the patient's part to the continued flexion of the head will be felt. I have called attention to the value of this "head test" elsewhere (56). This sign is often given by patients in whom the movement of the eyes has disappeared, and is very similar to the tremor found in neurasthenia and in old age, but is generally of a coarser nature, and increases in intensity for some time. Nystagmus may be obtained easily one day and with difficulty the next, and for this reason a second examination is sometimes necessary.

When movement of the eyes is present its character must be noted. As I have said before, the true movement of miners' nystagmus is a rotatory one, and if the movement is purely lateral and unequal on both sides grave suspicions should be aroused. The case may belong to one of the group of nervous disease, such as syringomyelia or disseminated sclerosis, which give the symptom of nystagmus. In these diseases the movement is generally lateral, and may be more marked on one side than the other. In a case of right extracerebellar tumour the movements were fine, and at rate of 300 a minute looking to the left, coarse and rate of 40 looking to the right. A general examination should always be made if there is any doubt of the case. The list of diseases in which nystagmus is found is a very long one. Nystagmus may be congenital or acquired. In the congenital form it occurs in some rare diseases of the choroid or retina, such as retinitis pigmentosa, congenital cataract, and corneal nebulae. It is also sometimes found in cases of error of refraction. In the acquired form it is found first in the disease in question, miners' nystagmus; then as a symptom of one of the group of nervous diseases mentioned above; in toxic conditions; and finally, as Barany has shown, it may be present after rotation, syringing the ears with hot or cold water, alteration of air pressure or galvanism to the head (Brain 29, p. 283). If a more detailed list is required, I must refer my readers to Wildbrand and Saenger, *Neurologie des Auges*.

Nystagmus is always found in the complete albino, and in my district there is a family containing three male albinos all working underground. The nystagmus in these cases persists below the horizontal, but is not accompanied by any subjective sensation. The vision in all three is very bad, being only $\frac{2}{24}$. The nystagmus is purely lateral in two cases, but the third lad shows a rotatory movement very similar to that seen in miners' nystagmus.

Voluntary nystagmus has been described by Nettleship (64).

In one case there was a rapid lateral movement at will, in the second case a house surgeon was able to produce lateral nystagmus by strongly converging his eyes. Mauersberg (60) describes two cases and quotes references to nine others. Stirling (109) quotes one case of voluntary nystagmus. I have seen one case in a medical man who was able to produce lateral movement by spinning rapidly on his toes.

A few cases illustrating difficulties in diagnosis will be described:—

(A) A chemist, age 32, left eye lost at age of nine months. No subjective symptoms, although the remaining eye is constantly moving. V less than 1/60 without glasses. Wearing - 8D vertical, - 9D horizontal for the last six years. Coarse horizontal nystagmus with an occasional rotatory movement. Eyelids twitch when he has "a cold in the eye." This gentleman has never been underground, and the nystagmus is due to the error of refraction present.

(B) Ostler, age 45, underground six years. Headache, giddiness, loss of sight and diplopia. No movement complained of, but he claims he is suffering from nystagmus. No nystagmus found on the most searching tests, but on ophthalmoscopic examination optic neuritis was found in both eyes.

(C) Lad of 14. Sent to me for examination. He has never been underground and has no symptoms. He was only in standard 2 when he left school, and stuttered badly. There was marked lateral nystagmus with a very occasional rotatory turn. V = 6/6, no error of refraction present. There was marked internal strabismus of the left eye and twitching of the orbicularis. If this lad had worked underground the difficulty of diagnosis would have been great.

(D) Collier, age 42, underground 30 years. All the subjective symptoms of nystagmus are present, and came on, according to the man, after an accident to the right eye. He was given a certificate by the certifying surgeon as suffering from nystagmus. The company appealed, and the medical referee decided against the man. I saw the man some months later and could detect no sign of nystagmus. He had extensive opacity of the right cornea with a dilated pupil not reacting to light, ptosis of the eyelids, and absent knee jerks.

(E) Collier, age 43, underground 30 years. Onset of symptoms about 12 months ago following a blow on the eye. He has all the symptoms of nystagmus—movements, night blindness, photophobia, and headache. His vision rapidly failed until at present he is only able to count fingers. Right pupil dilated, both pupils fail to react to light and doubtfully to accommodation. Knee jerks present. Optic atrophy of both discs present. On extreme elevation, slight nystagmus was found. In this case the incapacity was due entirely



FIG. 40.—TWO YOUNG ALBINOS WHO ARE WORKING UNDERGROUND AS
COLLIER BOYS.

to the presence of optic atrophy, which probably resulted from a cerebral tumour while the nystagmus present may have been due to the same cause.

(F) Collier. The man stopped work on account of pain across eyebrows and redness of his eyes. Certified. On examination I found a recent attack of iritis in one eye and evidence of old iritis in the other. On appeal to the medical referee the man's claim was disallowed.

Cases of High Myopia.

See Case A.

(Case 276) Collier, 39, underground 23 years. In this case the medical officer of the company contested the certificate of the certifying surgeon, but the man's claim was upheld by the medical referee. I saw the case after he had been working on the surface for two years, and at that time could not detect any nystagmus. It is interesting to note he had tremor of the head. $V = 1/24$ increased to $6/12$ with $-5D$ in each eye. He had never worn glasses.

(294) Collier, age 18, underground two years. Marked myopic astigmatism. Irregular movements of the eyes, but no definite nystagmus. He was given work outside but not allowed any compensation.

$$\text{Error. } \begin{array}{c} -3 \\ + \end{array} - 5 \text{ in both eyes.}$$

(295) Collier, 26, underground 11 years. Myopia $-7D$ in each eye. Well marked nystagmus.

(433) Collier's lad, 25, underground 13 years. Indefinite movements of eyes.

$$\text{Error. } \begin{array}{c} -5 \\ + \end{array} - 5.5 \text{ in both eyes.}$$

(441) Collier, 42, underground 25 years. Vision less than $1/24$, improved by $-15D$.

These cases of high myopia give rise to great trouble in diagnosis, the movement present is not the typical rotatory one, but rather an unsteadiness of the eyeballs. If any such unsteadiness is present in an underground worker, a certificate is readily obtained, and it is almost impossible to contest such a case. It is in these cases that the "secondary" signs, head tremor and nictitation, may be of value. Norman (66) "Children born with very high refractive errors may also be the subjects of nystagmus, in fact, I have personally investigated seven cases of juvenile nystagmus, in which the only apparent cause for the non-development of steady fixation was a high error of refraction."

Cataract.

(428) Collier, 53, underground 22 years. Onset of symptoms for the last twelve months, chief complaint loss of sight. $V = 1/24$ right, left eye P.L. Well marked cataract in the left eye, commencing cataract in the right eye. Slight nystagmus seen in the dark. The incapacity in this case is solely due to the cataract present.

(484) Collier, 63, underground 40 years. Right eye lost 35 years ago. Sight quite good up to two weeks ago, when it became dim and obscured by large specks floating about. The candle flame appears red. Vision = fingers. There is well-marked nystagmus, but no subjective symptom of movement. There is a cataract in the only eye, and this is the cause of incapacity.

(292) Collier, 59, underground 48 years. Cataract and old iritis in both eyes. Slight nystagmus on extreme elevation $V = 1/60$. Incapacity for work in this case is due to the cataract.

A Case of Tabes with Nystagmus.

(254) Collier, age 55, underground 48 years. All the subjective symptoms present, but no nystagmus found on examination. The doctor told me nystagmus had been marked. Pupils react to accommodation, but not to light, marked inco-ordination, absent knee jerks.

Nystagmus with Very Fine Movement.

(219) Collier, 38, underground 12 years. This case is interesting because the doctor thought the man a malingerer. The nystagmus was rotatory and obtained at 10 degs., it was so fine that it was very difficult to detect. I have had several such cases, where, owing to the limited movements of the eyes, the nystagmus was difficult to detect.

Elworthy is thinking of these cases when he says that the examiner should have good eyesight.

The difficulty of diagnosis in cases of nystagmus is, as a rule, very slight. The following figures were taken from the Blue Books of Statistics of Compensation :—

TABLE 33.

	Certificates granted.	Certificates refused.
1908	319	7
1909	549	21
1910	809	24

Since printing Tables 33 and 34 the statistics for 1911 have been published, and are given below:—

TABLE 33.

	Certificates granted.	Certificates refused.
1908	319	7
1909	549	21
1910	809	24
1911	1,251	29

TABLE 34.

	Appeals.	Decision upset.
1908	35	15
1909	98	41
1910	152	55
1911	312	57

The same books give the number of appeals against the certificate of the certifying surgeon for *all* Industrial Diseases:—

TABLE 34.

	Appeals.	Decision upset.
1908	35	15
1909	98	41
1910	152	55

Malingering.

Is it possible to simulate nystagmus? I do not think it is, except in very rare cases. Many men, however, who suffer from the disease can produce nystagmus at will by several methods, such as bending down rapidly, shaking their heads and holding their heads obliquely.

The cases of voluntary nystagmus quoted (*see* p. 104), about a dozen in all, appear to be all cases of lateral nystagmus. It is then difficult or almost impossible for the man to simulate the movement of the disease, but it is very common to find men who exaggerate their symptoms and remain idle longer than they should. Owing to the great difficulty in deciding to what extent the man is incapacitated by observing the objective signs alone, the medical man is compelled to trust largely to the patient's own statement. Some men are able to continue working although their eyes are continually moving, while other men are incapacitated by a trifling movement. Several men have tried to simulate nystagmus by violently blinking their eyelids, and genuine cases often resort to the same trick when they wish to impress the doctor. It is because of the ease with which this "clonic spasm of the eyelids" can be simulated that its inclusion in the Schedule of Industrial Diseases would be a mistake. One rather humorous patient, who had been charged by the manager with malingering, took the extreme course the next time the two met of walking directly into him, and having almost succeeded in knocking his superior down, apologised by saying he could not see him.

1. Case (27) This man had an injury to his foot for which he received compensation, which was stopped on a certain day. Within

a week the man brought a certificate that he was suffering from nystagmus. Nystagmus was present.

2. A collier had been paid compensation for a very doubtful injury to his back. When payment was stopped he immediately started to complain of his eyes, and blinked violently while they were being examined. No nystagmus was present, and the man was paid no further compensation.

Case (45). Collier. This man quarrelled with the manager and was discharged. He immediately brought a certificate for nystagmus, which was undoubtedly present.

This last type of case is common, nystagmus is present but is only brought forward when the man is in trouble.

Case (141) Collier, age 31. This man was idle for six months on account of nystagmus, and then worked on the surface for four months. He finally returned to work at the coal face, and all went well until he left twelve feet of coal without a sprag. The manager, forgetting for the moment that the man had suffered from nystagmus, sacked him. The man immediately came to me and told me that he had failed to work on account of his nystagmus. I could not detect any movement of the eyes.

PROGNOSIS.

Slight cases recover quickly and completely, but severe cases may be incapacitated for years. The table given on p. 20 may be referred to. Prognosis in individual cases depends on several factors, which will be discussed separately. The conclusions arrived at must not be taken as absolute.

Age.

Cases at the extremes of age are unfavourable. The fact that a young man is attacked shows that he is specially liable to the disease, while the older the patient the more unlikely his recovery. Apart from the exception of cases under the age of 22, it may be said that the younger the patient the greater his chance of recovery.

Length of Symptoms before Failure.

The sooner a man gives up work after the onset of symptoms the quicker his recovery. Some of my worse cases have been in men who have struggled against the disease for years. Cases who fail suddenly are sometimes very marked.

Degree of Elevation Necessary to Produce Nystagmus.

Presence of nystagmus in the horizontal plane, and even more so in a plane below the horizontal, should always be taken as a mark of the severity of the attack. There is one fallacy, however. After nystagmus has once been obtained it may persist in the horizontal plane. These cases should not be regarded as "horizontal." The more difficult the nystagmus is to obtain, the better the prognosis.

Visual Acuity.

The better the vision the better the prognosis, and progress can often be measured by the improvement shown in reading the test types. Vision rapidly failing at the same sitting, showing easy fatigue of the patient, must be taken as a bad sign.

Presence of Error of Refraction.

If a marked error is present the case is not likely to recover quickly, even when suitable glasses are provided.

Ocular Defects.

Injuries to the eyes, and especially to the cornea, must also be taken into consideration, while the onset of cataract is to be looked upon as a very bad sign.

Tremor of the Head and Nictitation.

These signs are rarely absent in severe cases, and both may persist after all movement of the eyes has disappeared. In some of the most severe cases the tremor spreads to the muscles at the back of the neck and shoulder. Ataxy is also a bad sign. Miners' nystagmus is a protracted disease, but when complicated by the syndrome known as traumatic neurosis the prognosis is the most hopeless of all. The general state of health is also important, and must be taken into consideration.

Alcohol.

The man incapacitated by nystagmus has so much leisure that the temptation to drink is almost irresistible, and this is one of the chief reasons why employment should be found at as early a date as possible.

There is no doubt whatever that alcohol has a very harmful effect on the progress of recovery from the disease. A bout of drinking will undo all the improvement effected by weeks of rest, and often converts a latent into a manifest attack. A vicious circle is brought into play:—



Excessive smoking has the same effect, though to a much less marked degree, as indulgence in alcohol.

CHAPTER VIII.

The Etiology of Nystagmus.

AT the coal face there are (1) feeble illumination, and (2) a black and almost uniform surface towards which vision is directed. Maddox (58, p. 98) states "In the dark and with an absolutely homogenous field before them the eyes are always moving." One cannot accurately fix a point on a uniform surface, and whenever the eyes cannot be accurately fixed there is a tendency to movement. This tendency to movement may be increased by the fact that the perifoveal region of the retina is more sensitive to dim light than the foveal (Edridge-Green 39, 38), and consequently in an imperfect light there would be a reason for using this region more frequently. The outer part of the retina is also more sensitive to the movements of surrounding objects, and it is this part of the retina which guards us against the danger of striking moving bodies. As a result of working for long periods in the comparative darkness of the pit, the cells of the retina probably lose their power of producing sufficient pigment for exact vision. The cramped attitude, which the miner often has to assume, also helps to derange the centres of equilibration. The collier requires accurate fixation to perform his work satisfactorily, and to obtain this he strains his eyes and uses his accommodation excessively. If he is suffering from error of refraction, the strain must be more marked. The total result is that there is, on the one hand, imperfect fixation leading to the transmission of indefinite impulses to the brain, and on the other excessive reinforcement from the higher brain; failure of co-ordination results and nystagmus ensues.

Failure of co-ordination is due to :—

- (1). Imperfect fixation.
 - (a). Feeble illumination.
 - (b). Uniform black surface.
 - (c). Lack of retinal pigment, natural or acquired.
- (2). Excessive accommodation.
 - (a). Efforts of higher centres.
 - (b). Error of refraction.
- (3). Disturbances of equilibrium.
 - Position of the body at work.
- (4). Movements of the eyes in the interest of vision.

These factors will now be discussed in detail.

Feeble Illumination.

Everybody agrees that the light at the coal face is small, but hitherto no measurements have been published showing how small it is. It has also been assumed that the light in a naked light pit is very slightly superior to that given in a safety lamp pit, whereas, really, it is from five to six times as great. An illumination of $1/50$ — $1/70$ of a foot-candle is very feeble, and yet this is the amount which falls on the coal face in a safety lamp pit. The amount reflected from the coal face, owing to the great absorption by the coal, is much less, and may be estimated as follows :—Coal absorbs from 85 to 97 per cent. of all incident light, therefore the amount reflected will be from 15 per cent. of $1/50$ to 3 per cent. of $1/70$ of a foot-candle, or an amount varying from $\cdot 003$ to $\cdot 0004$ of a foot-candle. These amounts can be read directly, but only with great difficulty and with a large margin of error.

The illumination falling on the coal face in an open light pit may be equal to $1/10$ of a foot-candle or more, although even in these pits the illumination may fall to $1/25$ of a foot-candle. It seems clear to me that in feeble illumination, caused by the limited amount of light given by the safety lamp, and by the almost total absorption which takes place at the coal face and the coal blackened surroundings, we have the root of the trouble.

Parsons (76A), in an interesting paper on "Scotopia or Vision in Dull Illumination," brings forward the views of W. Nagel and Von Kreis. Scotopia depends on dark adaptation of the retina, the peripheral part of which, especially from 10 to 20 degrees from the fovea, is the most sensitive to dull illumination. The minimal stimulus which will produce sensation of light is best seen by the

peripheral part of the retina; for example, if the Pleiades are viewed by indirect fixation a greater number of stars will be seen than if the cluster is fixed directly. The fovea is the most sensitive part of the retina to light adaptation or to photopic vision, but it has very little dark adaptation, and may be called the region of physiological night-blindness. Scotopia is in every way allied to complete colour-blindness, and is quite distinct from photopic vision.

The anatomical differences between the peripheral and the central part of the retina have led many observers, from Helmholtz and Schultze to Von Kries, to suggest a different function for the two parts, represented respectively by the rods and cones. Schultze said that the rods subserve impressions of simple light without discrimination of colour, and that the cones were the organ of colour perception.

Von Kries brings forward the "duplicity theory," in which the rods are the organ of scotopic vision, the cones of photopic vision. "The rods are susceptible of very marked alterations of adaptation, whereby all effective stimuli excite colour-free sensations of light, which vary in intensity in accordance with the scotopic luminosity curve. The cones, on the other hand, are susceptible of only slight alterations in adaptation; they are colour sensitive, and react with an intensity which varies according to the photopic luminosity curve, being relatively more excitable to the rays of long wavelength than the rods." . . . "Apart from the obvious arguments deduced from foveal vision and the absence of rods in this region, and so on, the strongest argument in favour of the theory is probably the fact that the visual purple is limited to the rods, and that the curve of chemical sensitiveness of this substance coincides with the scotopic luminosity curve." The reader is referred to the paper itself (76A).

In the coal mine, with the dull illumination and the absence of colour, dark adaptation of the retina must always be present. The peripheral portion of the retina is thus brought into use, and central fixation, with its accompanying steadiness of the eyeballs, is lost. In this manner a tendency to movement is set up. In miners' nystagmus night blindness is common. Does this mean that the scotopic function of the retina has been interfered with, and that a condition similar to that naturally obtaining in the fovea is present over the whole retina? Is this night blindness the

result of deficient visual purple in the retina? Mr. Parsons states that the scotopic luminosity curve varies with the curve of chemical sensitiveness of the visual purple (*see above*), or, in other words, with the amount of visual purple present. Failure of dark adaptation may quite well be the ultimate cause of miners' nystagmus.

It is impossible, as Nuel says, to alter the structure of the coal which "remains in spite of all a black and crystalline substance," and no whitewashing or colour scheme is within the limits of practical mining. Improvement of the illumination alone remains, and it seems to me that in advocating a better light the exponents of the position theory give their case away. They are willing to take advantage of a better light, but do not draw the obvious conclusion that the lack of light is the prime cause of the disease. For measurements of the light present at the coal face, I must refer the reader to pp. 65-70.

Uniformity of Surface.

In some cases where the back of the slip has been reached, the surface is absolutely uniform and capable of absorbing, as I have shown, almost all the light which falls upon it. It is easier, when the transverse section of the coal is worked, to fix a point on its surface from which a little light is reflected. I do not myself attach much importance to the influence of the facets of the coal face. According to Butler and Nuel an impairment of binocular vision results from the reflection of light from the facets, but nystagmus occurs in one-eyed men, and in men who never work at the coal face; and the amount of light reflected is so very small that it cannot have much influence. In naked light pits also a transverse fracture of the coal is always present, while in the steam coal pit the back of the slip is often the only surface the collier sees.

Lack of Retinal Pigment.

The figures which I produce in support of my view that work in the coal mine diminishes the visual acuity are suggestive if not conclusive. I have shown (1) that visual acuity is very poor in men suffering from nystagmus, (2) that even in normal people full vision is not common after several years' underground work, (3) that nystagmus occurs more frequently in fair, light-haired people than in the darker type. Other points which bear on the

question are (1) the more frequent occurrence of nystagmus in winter than in summer, (2) the greater probability of cure in summer, (3) the dread of light, showing sensitiveness of the retina, which is so often present in the early stages of the disease; and (4) the analogy that may be drawn from the occurrence of nystagmus in albinos. Usher (123) describes the microscopical examination of the eyes of a case of congenital nystagmus. There were marked changes in the macula, but there was no evidence of any lack of retinal pigment. The way in which work in a coal mine causes lack of pigment may be explained as follows. For the perception of light the production of visual purple is necessary, and visual purple is only produced in the presence of light. If a man spends nearly six months of the year with only an occasional glimpse of the sun on a Sunday, as is the case of a miner who goes to work in winter before the sun rises, and comes back shortly before it sets, the cells of his retina do not get sufficient work to do, and lose their power of producing sufficient visual purple for exact vision. The Eight Hours Act should have a beneficial effect in this connection, and already some authorities, Rutten especially, are calling for a further reduction in the number of hours worked. After all, man was not intended for work underground, and Nature takes the revenge she always demands.

Excessive Accommodation.

The higher centres strive by enforced application to make up for the deficient light present. Convergence of the eyes, which accompanies strong efforts of accommodation, is frequently seen, and in some cases attributed by the men to the onset of nystagmus. Romi  , Thompson and Court, all lay stress on the strain which results from the bad light present. Error of refraction must help to increase this strain, and the frequent occurrence of myopia does not really contradict this view as these cases were often astigmatic. I examined 46 horses for nystagmus without finding any trace of the disease. I picked out the oldest animals and those who had been longest in the pit. Some had been eight, nine, and even ten years underground without a break. Ten continuous years would more than correspond to 40 years as worked by the collier. Two cats were also examined, with a negative result. The horses work in the same feeble illumination as the collier, but as they have apparently two fields of vision, there is no need for any associated

movements of the eyes, and in any case there is no necessity for accurate fixation. "The lower animals have no central fixation, but vision is distributed over the entire surface of the retina" (Maddox 58, p. 100). Their eyes are therefore more suitable for seeing in the dark, and there would not be the same disturbance of vision as in man.

Disturbance of Equilibrium.

The awkward and constrained position which the miner has to assume must throw a strain on the centres of equilibrium. Snell, Dransart, and Nieden say that the elevation of regard is the chief factor in the production of the disease, and that it acts by producing a local myopathy of the elevator muscles of the eye. They call attention to the fact that nystagmus can only be brought out in many cases by asking the patient to raise his eyes, and maintain that the greater the elevation the more marked the nystagmus. This is perfectly true, but I think another explanation is more satisfactory. In the first place, it is not the elevator muscles which are affected, but the movements of elevation, in which all the muscles of the eye, with the exception of the internal and external recti, participate. All ocular muscles act in concert with one another, and the only simple movement present is the movement to the right or left, the result of the action of the internal and external recti muscles, and even here the opposite muscles of each eye act together. The movements of elevation are the weakest of all, and would naturally be the first group to suffer in any derangement of the centres. We do not use the movements of elevation to any extent, although the introduction of aeroplanes may have an effect in a few centuries, and the ease with which they can be tired is readily shown by the Academy headache which follows a visit to the picture galleries. If the movements of the eyes in the vertical plane are noticed it will be seen that in all positions below the horizontal there is an associated convergence, while in all positions above there is a tendency to divergence. The eyes are in the position of maximum stability when depressed and converged, and in the position of minimum stability when elevated. Assuming that the centres governing the associated movements of the eyes are deranged, it would follow that the effects would be first and chiefly noticed when the eyes are elevated. In the coal mine, elevation of the eyes is frequently necessary. The firemen in

examining the roof, the ripper whose work consists in making more room by cutting away the roof, the timbermen and the repairer, all have to work at times with elevated direction of regard. The collier, even when engaged in holing, very rarely has to elevate his eyes, except for the examination of the roof. I disagree entirely with the statement of Snell, which is to the effect that elevation is constant and essential in the process of holing.

The views of Peters (80) are given on p. 32. He calls attention to the backward carriage of the head, and asks if it is primary or secondary. I think the attitude is assumed in order to bring the eyes into a relative position of depression and convergence, the position of maximum stability, and at the same time to direct the plane of vision horizontally forward. Assume the man to be looking downwards and inwards, his eyes are then in a position of stability, but he is unable to see what is going on in front of him. In order to do this he throws his head back, keeping his eyes in the same position relative to the head. He is now able to look in front of him, and at the same time keep his eyes steady. One of the great objections to the position hypothesis is that it is necessary to place miners' nystagmus in a category by itself, and regard it as quite distinct from all other varieties of nystagmus. If the hypothesis of inco-ordination is correct, miners' nystagmus is at once brought into line with the other varieties. The connection between the labyrinth and the ocular muscles is intimate, and Rutten (98) says, "It has been established and admitted by everybody that the labyrinth is the great regulator of the ocular movements." Any alteration in position, such as bending rapidly, shaking the head or holding it obliquely, produces disturbances in the labyrinth, and helps to bring about the degree of inco-ordination necessary for the production of nystagmus. While admitting that position has an influence, I still hold to the view that the essential factor in the production of the disease is the feeble illumination present in the mine. Position alone has no influence, and no cases of nystagmus have been recorded among house decorators or whitewashers who have to work with elevated gaze. The cases of nystagmus, such as Snell's printer (102), Nuel's marble polisher (72), and a case of an accountant who had to add up long columns of figures, may be balanced by such cases as (1) Frost's (45) (*Trans. Ophth. Soc.* vol. 14, p. 245), where a man who had been washing cabs in a badly lit yard developed nystagmus, and a case which the

late Dr. Brown, of Tredegar, related to me where a seamstress developed temporary nystagmus after executing a large mourning order with great urgency. In all of these cases the nystagmus was probably more of the nature of a coincidence and criticism which Butler applied to Snell's case, that it was more of the nature of asthenopia with nystagmoid movements, can be justly applied to all.

Movements of the Eyes in the Interests of Vision.

Arlt, in 1867, quoted by Dransart in 1877 (28) said that nystagmus was due to an attempt on the part of the eyes to bring a fresh part of the retina into play in order to secure better vision, and Edridge-Green in 1912 (40) gives the same explanation. Maddox says, "the object of ocular movements is to bring the best point of the retina to bear upon objects looked at, and thus obtain the keenest possible vision of whatever part engages the will or the attention of the moment." I have made the suggestion that the central portion of the retina may be worn out. Many men are unable to read the test types when looking directly at them, while, if they turn the head so as to look sideways the vision is much better. This, however, may be due either to the good effect of bringing a fresh portion of the retina to bear on the point engaged, or to the greater stability of the eyes in the extreme lateral position.

Influence of Accident.

Accident is a very potent cause in converting a latent into a manifest attack—so potent, indeed, that many men would probably never have had any symptoms if they had not met with an accident. I must also point out that the men who work at the coal face are more subject to accident and to nystagmus than any other class of underground worker.

Accidents are much more numerous in steam coal collieries, where nystagmus is frequent, than in open-light collieries, where nystagmus is rare.

GENERAL NYSTAGMUS.

In discussing the causes of miners' nystagmus it will be well to consider the causes of nystagmus generally. Turner and Stewart (122) in their text book of Nervous Diseases give the following classification :—

1. Interference with the co-ordinating centres and connections of the ocular muscles.
2. In conditions associated with interference with vision such as optic atrophy, error of refraction and albinism.
3. From strain and fatigue of the ocular muscles, as in high myopia and miners' nystagmus.
4. As a congenital condition of central origin.
5. Spontaneous.

The table has been condensed, but it is obvious that the list is an extensive one, and that nystagmus is a condition readily brought out.

The ease with which nystagmus follows rotation of the body and syringing of the ears shows that the centres which control the associated movements of the eyes are easily disturbed. If the list be considered it will be seen that inco-ordination is at the root of every case. In the first and fourth groups this is granted, in the second group imperfect impulses to the brain disturb the centres. In the fifth the methods used to produce the nystagmus, such as excessive convergence (*see* p. 104), have the effect of throwing the central mechanism out of gear. The third group remains, and I have endeavoured to show that this group is not an exception. We have the sudden onset in many cases, and the character of the movements; the methods used to bring out the nystagmus all pointing to a central lesion.

A brief *résumé* of the views of some of the leading authorities on nystagmus generally may be useful. The work of Barany (3) has shown the intimate connection between the labyrinth and the production of nystagmus. Oglesby (73), after speaking of nystagmus generally, says that venous engorgement of the medulla when the neck is bent is the cause of miners' nystagmus. Sir W. Gowers (46) thinks that nystagmus is due to an alternating contraction of opposing muscles. He thinks there is probably a central lesion in or near the mid brain and pons, and in the cerebellum, "mid brain ocular centre." The automatic action of the centre becomes dominant with extreme readiness; the grasp of the centre by volition is of slender energy, and unable to overcome any tendency to insubordination. Wilbrand (126) attributes nystagmus to the disorder of the centre for common reflex action of the eyeballs, or of the volitional impulse, so as to produce a want of harmony between the two.

Miners' Nystagmus.

Rutten says that the nystagmus is due to an attempt made by the eyes to counteract any alteration of the position of the head. Snell, Nieden, and Dransart say that the disease is a local myopathy involving the elevator muscles of the eye. Jeaffreson thinks there is a dissociation of centres normally acting together. Elworthy says the disease is due to a lack of colour relief in the coal mine. Romi  , Court, and Thompson all say the condition is due to the strain resulting from working in a deficient light. Peters thinks the origin may be in the labyrinth. Butler and Nuel think the crystalline nature of the coal has an important effect. Reid thinks there is a loss of central fixation and a disturbance of equilibrium. Edridge-Green suggests that movement is in the interest of vision at first, and then becomes permanent.

MOVEMENTS OF THE EYELIDS.

Why should movements of the eyelids and eyebrows be present in cases of nystagmus? One explanation proposed to me by several mining men is that the collier involuntarily blinks at the moment the pick strikes the coal, in order to prevent injury to his eyes. This habit becomes confirmed, and finally persists. This view is not correct.

The movements of the eyelids are of two forms. The first is a blinking movement, the result of photophobia, or of volition on the part of the patient; the second is more of the nature of a tremor which spreads to the eyebrows and muscles of the forehead. When one group of muscles is deranged there is always a tendency for the other groups of muscles functionally related to this group to become affected. Thus an epilepsy confined at first to the thumb may spread to and affect the muscles of the whole arm. In miners' nystagmus the derangement spreads from the eye muscles proper to the functionally related muscles of the eyelids and eyebrows. In the same way the intimate connection between the position of the eyes and that of the head also explains the involvement of the head muscles in bad cases.

I have already given an explanation of the position in which the head is held in long standing cases.

In the mid brain there are probably several centres, each capable

of independent action, and connected with the various movements of the eyes. These centres are under the control of a higher centre, the mid brain ocular centre of Gowers, which receives the peripheral impulses and co-ordinates the movements of the eyes by regulating and combining the individual action of these lower centres. Freed from the influence of this higher centre, the lower centres take upon themselves a reflex action and act independently of one another. In nystagmus, messages coming from the eyes and body generally to the controlling ocular centre are inexact and incomplete, and the commands issuing from this centre are consequently indefinite. The will now endeavours to guide this controlling centre by way of extra accommodation and attention, and to an extent succeeds in rendering these inexact messages more exact. A state of equilibrium, the latent stage of the disease, has now been reached, and this condition may be permanent. In other cases the ocular centre is unable to stand the stress of the conflicting forces acting upon it, and breaks down more or less completely, leaving the lower centres untrammelled by any restraining influence and free to indulge their own particular movements. Manifest or symptomatic nystagmus is now present, and the severity of the attack depends on the extent of break down of the controlling centre in the mid brain.

In order to make my meaning clear to the non-medical reader I will try to give an analogy by comparing the centres of the brain to a secondary battery, or accumulator. An accumulator is charged by connecting its terminals with wires conveying electric current. If charged properly at the correct ampère, the battery retains a certain quantity of potential electric power which is ready for use at any moment. If the cell is charged too quickly, or at an excessive ampère, and still more, if the terminals are connected to the wrong wires, the cell loses its power of retaining its charge. The cell will only yield its maximum when properly charged. The nerve centres in the mid brain are accumulators, they are charged by the messages which come from the eyes and from the body generally through the inner ear, and they discharge themselves in regulating the movements of the eyes, and in maintaining the equilibrium of the body. But suppose this charging to be either incorrect or deficient, then the nerve centres and the battery alike are unable to act properly. In the case of the battery the electrician comes along, and by careful recharging or by replace-

ment of damaged parts, is able to give the cell a new lease of life. What happens in the case of the nerve centre? Here, the higher centres in the large brain take the place of the electrician, and by reinforcement of the lower centres, are able to tide over the difficulty for a time. Their reinforcement soon becomes insufficient, and a break down is inevitable. The lower nerve centres are short circuited, and discharge themselves irregularly in the inco-ordinate movements of the eyes known as nystagmus.

It will perhaps be interesting to give the views of the miners themselves on nystagmus. The majority are quite emphatic, and say the trouble is all due to the bad light given by the safety lamp. They also hold strongly that a man who changes from a naked light mine to a safety lamp mine feels the want of light more than a man who has always worked with safety lamps. Many men deliberately change from a safety lamp pit to a candle pit when they first notice trouble with their eyes. Men have often complained to me that the oil used in certain collieries was bad, and that the lamps were not properly cleaned. The experienced collier always takes great care of his lamp, and places it so that the light does not fall into his eyes. Many men have told me that they have had more trouble when they hole, or when they have to dress the coal above the level of their eyes. All agree in saying that excitement and a spell of extra hard work aggravate the complaint. The men are also well aware of the importance of efficient ventilation in order to obtain a good light. I have had many conversations with experienced colliers, and have asked them if nystagmus was as prevalent in their younger days. The reply has always been "No," and the men have told me that if a man had nystagmus formerly he worked on the surface for a few months, and then returned to his old work underground. One collier told me bluntly that he thought the reason of the increase in the number of cases of nystagmus, and especially the prevalence among young men, was the early marriage of young lads, who begat children before they themselves were mature. "They have no strength left in them."

I have not been able to discover any old remedies and superstitions about the disease, but some men advocate the bathing of the eyes every morning in cold water, while others pin their faith to the efficacy of ear rings. A colliery manager should always regard a man wearing ear rings with suspicion. Most men say

that with a little rest and employment on the surface, recovery soon comes, and, as I have already said, many change from a safety lamp pit to a candle pit.

I give below a letter from a miner :—

“I am a miner, and a sufferer of the disease, and I thought if I gave you my experience of it, the statement might be of use to you in your further enquiries. I am 58 years of age, and have worked in these mines (ironstone) for about 42 years. I was first attacked by the complaint when I was about 30 years of age, so that I have been afflicted about 28 years; the first attack was so severe that I submitted to medical treatment for two months, but did not improve (in fact got worse) so I got employment at the steelworks near here, where I was exposed to excessive heat from hot metal, which caused a profuse perspiration. The employment was of a light character. In about twelve months I was completely recovered, and foolishly got employment in the mines again. I had only been working a few weeks when I was again attacked with this affliction of the eyes, and have been troubled with it ever since (1887) in varying degrees. That the want of proper light is the cause of it seems reasonable, because my experience is that when I get out to the daylight, it will pass away almost immediately, but I am inclined to think there are other causes besides the poor light we have to work in. The lights here are naked candles, but the atmosphere is often laden with dense smoke, so that it is often difficult to see during the day. I think another cause is the excessive speed one has to work, in order to turn out the amount of tonnage expected of us, because that is when I am troubled, when I am working at high speed. I can do my work in a fairly leisurely way and not be troubled, or when in a troubled condition it will pass away in a few seconds by resting. I am inclined to hold this view because I have seen men when working in a savage manner shake in every limb, just as in my case the eyes do. But there may be other causes that go to produce the trouble, for I am affected in an alarming degree by any mental excess, such as getting into a heated argument about any particular matter, or even sitting or reading for some time, and my experience during this enforced idleness on account of the strike has been quite disconcerting. Instead of improving (which I have in outward appearance), in this particular trouble I have got decidedly worse—so bad, indeed, that I cannot bear any excitement—even in such good light as electricity gives in the large towns, I have to move about in a slow and careful manner, so that perhaps a man’s constitutional condition has something to do with it, though I have nothing to complain of, except this matter of the eyes. . . . Any exertion in the mine, or even in the dark anywhere, causes a violent motion (apparently) of everything, of course it is the eyes that are moving, it is not a swimming motion as is usual after one has had too much beer, but more like what occurs if you set a string in motion holding the ends in each

hand with a button or something attached to the middle of it. I don't think I can say any more to explain my condition, but hope this will help you in your enquiries."

The letter is so interesting that I offer no apology for giving it in full, and the letter itself is worth careful study, if only from a psychological standpoint.

It is sometimes necessary to introduce safety lamps in the place of candles. Whenever this is done, it is usual to increase the cutting price of the coal by a penny or more a ton. The men say it is much harder to work with the safety lamps than with candles. When candles are used the men provide their own, but the cost of upkeep of the safety lamps is always borne by the employer.

CHAPTER IX.

Preventive Measures and Treatment.

THE results of this investigation show clearly that the most important preventive measure is improvement in the lighting power of the miner's lamp. The readings I have taken of the safety lamp, as used at the coal face, show that the amount of light given is much less than the credited standard of '6 to '7 candle-power. I have also shown that a lamp may give only one-third of its usual amount of light when dirty, and that the importance of careful cleaning with machine brushes cannot be over-estimated. Great care should be taken to keep the lamp in proper repair, and to replace any loose and worn out burner or washer. After long use, the screw thread of the oil reservoir becomes worn; the reservoir will then screw up so far as to bring the broad aspect of the flame opposite one of the supporting bars of the lamp, and only a half or three-quarter flame will be available. The difference between a full flame and the edge is appreciable, and as the total light given is so small all must be utilised.

Lamp full flame	'245 candle-power.
Lamp side flame	'215 „

A loss of over 12 per cent. of the light available.

The question of reflectors is also important, and I think a great improvement could be made in the safety lamps, and especially in an electric lamp by an arrangement of suitable reflectors. The photographs and readings on p. 87 show the great value of an additional 10 degrees of light.

Lamp with reflector	'65 candle-power.
Lamp without reflector.....	'50 „

A difference of 23 per cent.

The quality of the glass used is also important, and no streaks or flaws should be allowed. I tested an electric lamp lately, in

which the glass was so full of flaws, that a streaky light was obtained, and the lamp which was supposed to give 2 candle-power only gave '9 candle-power.

The question of oil is also important, and the Wolf lamp owes its brilliancy to the high flash point of the spirit used. Speaking generally, the heavy oils, such as colza, do not give so good a light as the mineral oils of a flash point of about 260 degs. Fahr. I have had several complaints about the quality of the oil used, from the men I have seen. Once in the Midlands I was told by two men that the oil used in a certain pit was very poor. I saw the certifying surgeon of that district and was told by him that he had more cases from this small pit than from any of the collieries around. The question of oil is so closely bound up with that of the lamp, that it is almost impossible to discuss the one without the other.

Every man on his way to and from the face should be compelled to use a shade at the back of his lamp. In many districts, where this has been the custom, any man omitting this precaution would be at once assailed by his fellow workmen. The dancing of the lamps in front is very trying to all, but it is fatal to a man with nystagmus. I have often been told by men that they have had to sit down "to let the lamps go by." These shades should be provided by the management, but can be readily improvised by means of a piece of cardboard or folded newspaper.

Use of Electric Lamps.

I do not think it possible to obtain a much greater increase in the candle-power of the oil safety lamp. Acetylene lamps give a good light, but they require so much care that their general use is not possible. The lamp of the future will be the electric lamp. There is no question that the electric lamp gives more light, but the great objections to its use in the past have been its uselessness as a gas detector, its unreliability, its original cost, and the cost of upkeep. The electric lamp cannot be used as a gas detector, and any attempt to combine an auxiliary safety lamp with it will add to its weight and lessen its utility. A safety lamp should be given out to a picked man in each small district, or the responsibility of gas testing left to the firemen. The reliability of the electric lamp has now been established, great improvements having lately been made in the manufacture of accumulators.



FIG. 41.—PHOTOGRAPH OF THREE SAFETY LAMPS RETURNED
AFTER ONE SHIFT FROM ONE COLLIERY.

The first lamp shows that the bonnet and gauze have been punctured by a blow from a mandril; the second lamp has had its bonnet bent by a fall; the third lamp shows a cracked glass, also the result of a blow from a mandril.

The expense of upkeep of a primary electric lamp prohibits its general use. An electric lamp compares very favourably with the ordinary oil lamp as far as safety is concerned. The oil safety lamp is only safe when properly used; if the gauze is allowed to get too hot, or if the lamp is moved too suddenly into a pocket of gas, it will cause ignition. The oil lamp when injured is converted into an open lamp, and a careless collier with a single blow of his pick may start a conflagration. The photograph (fig. 41) shows some of the dangers of the use of the modern safety lamp. The three lamps were all returned in one shift from one colliery.

If an electric lamp is damaged in the same way it is extinguished, and thus compares very favourably from the point of view of safety. The electric lamp costs much more than the oil lamp, but this is chiefly because the oil lamps are made in very large numbers, while the demand for electric lamps is small. Electric lamps can be obtained to-day for 15s., and in future will be cheaper. The cost of upkeep, if the proper plant is installed, is very small. Figures are given, in the section on safety lamps in Boulton's (6) "*Practical Coal Mining*," as to the relative cost of upkeep of oil and electric lamps. The upkeep of the Sussman lamp at the Murton colliery is given as 43d. per week for cost of labour, renewals, repairing, superintendence, and cleaning. The writer, Mr. Ashworth, says, "Comparing this table of costs" [for oil lamps] "with that for electric lamps at Murton colliery, it would appear that electric lamps of the Sussman type are actually cheaper per candle-power than oil lamps."

At Murton 2.11 oil lamps became extinguished per shift compared with .01 of the Sussman lamps. The life of the batteries was from ten to twelve months.

Electric lamps are also used at Altofts Colliery, Normanton, and I was told by the manager that it was the intention of the company to replace the oil lamps entirely by the electric lamps.

The first prize (£600) in the £1,000 international competition for the best miners' electric safety lamp has just been awarded to Mr. F. Faerber for his C.E.A.G. lamp, a photograph of which is shown (fig. 44).

The maker claims that the lamp is of 1.5 candle-power, and that it will burn continuously for 16 hours. It is guaranteed to be absolutely safe in the event of damage by a fall, and that, in pits in

which the lamp has been introduced, the upkeep is lower than that formerly experienced with oil lamps.

The lamp carries out the principle, on which I lay so much stress, of distributing the light over a large area.

See *Colliery Guardian*, No. 2,695, August 23, 1912.

The following photograph, fig. 42, which should be compared with the photographs, figs. 31-35, was taken from a skeleton form of an electric lamp which I have devised. The bulb is of 4 candle-power, and the photograph was obtained in exactly the same manner as those referred to above, the exposure, development and printing, were all carried out under the same conditions. The main principle of the lamp is that as much light as possible is obtained by the use of reflectors, which are shaped like truncated cones. In this manner the lower part of the field is well illuminated, and about 235 degs. of light area are obtained, as compared with the 180 or 170 of the oil lamp. The protecting cylinder of glass is held in position by the reflecting cones, and the upper part of the lamp is connected to the lower by firm rods at the sides only, leaving the front and back unobstructed. A removable back reflector might be added.

It is doubtful, at present, if a lamp giving more than 2 candle-power could be made sufficiently light for general use in the mine.

If any lamp manufacturer wishes to make use of these suggestions, I am quite willing for him to do so.

With the improvement of the light underground the collier will be able to turn out more coal, and the liability to accident will be lessened.

Work in a coal mine throws great strain upon the eyes, and only men with sound eyesight should be allowed to work underground. The table given on p. 15 shows that nystagmus is much more likely to occur in a man suffering from error of refraction than in a normal person. Simple tests should be put to all fresh men by the managers, and if the result is not satisfactory, the men should be referred to a medical man. The test I would suggest is the following:—A card with test types, placed in a good light, should be hung up at a distance of 6 metres, and the man asked to read the letters. If he is unable with both eyes to read the 6/9 line he should not be employed without examination by a medical man.

Where much holing is necessary, a reflector should always be used at the back of the lamp so as to throw as much light as

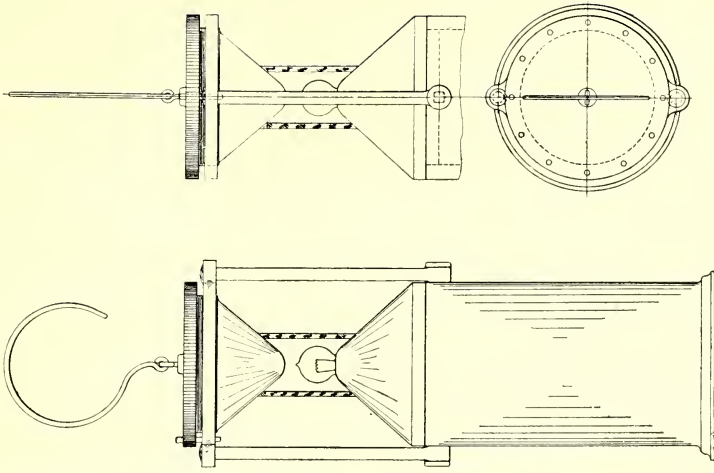


FIG. 43.

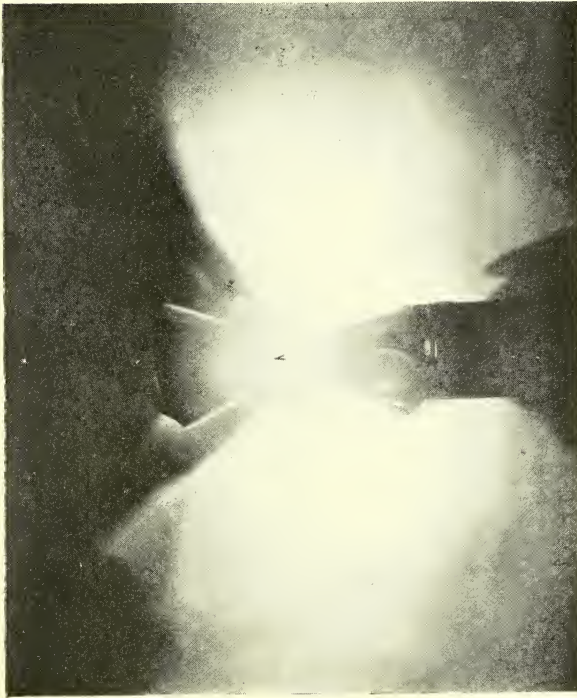


FIG. 42.—ELECTRIC SAFETY LAMP.

This is a photograph giving the rough outline of a proposed electric safety lamp. The great feature of the lamp is the conical reflectors, which enable a field of 235 degs. to be illuminated. Compare this photograph with figs. 31-35. The bulb is of 4 candle-power.

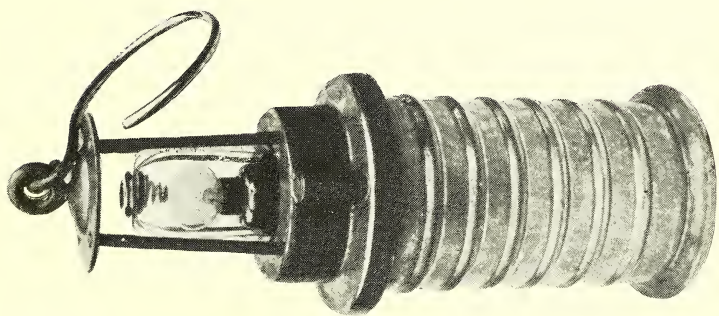


FIG. 44.—THE "CEAG" MINER'S
ELECTRIC LAMP.

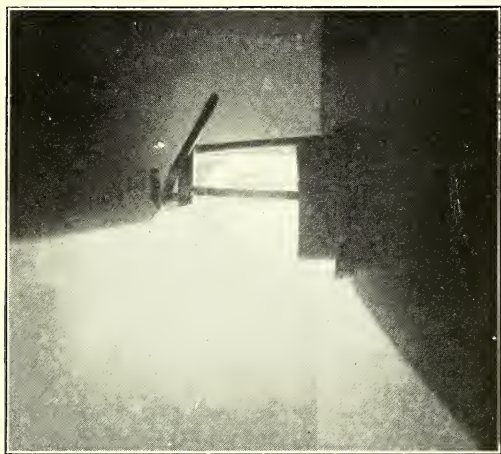


FIG. 45.—THE OLDHAM HEWERS' SHADOWLESS
ELECTRIC LAMP.

Compare photograph with figs. 31-34.

possible on the working face. In thin seams the introduction of coal-cutting machines may also help.

TABLE 35.—USE OF COAL CUTTING MACHINES. (43 collieries).

	Collieries.	Per cent. of nystagmus.
Extensively.....	6	0·49
Partly	15	0·73
Not used	22	0·81

The figures on p. 73, which give the influence of defective ventilation of the candle-power of the safety lamp or candle, show the importance of securing a good supply of air. The light given by a safety lamp falls very rapidly as the oxygen percentage of the air diminishes.

The effect of deficient ventilation on the general health must also be taken into consideration. The presence of dust in the air greatly diminishes the light, first of all by the absorption which takes place, and secondly by the clogging of the gauze of the lamp.

TREATMENT.

Very little space is devoted to the subject of treatment by most writers. Snell says that in most cases change of work is the only thing necessary, but lately the general opinion has been that the man should leave the pit at once. Many people have gone much further, and said that no man should return to work underground after an attack.

When the disease produces symptoms the man should leave the pit for a short time, and the sooner he follows this course the quicker will be his recovery. He should, if possible, work on the surface, as by this means he is less likely to become despondent and neurasthenic. The severe cases are unable to do anything, and need complete rest. Rest, and work out of the pit are the only specifics for nystagmus, and medical treatment, with the exception of the exhibition of the tonics, is of very little use. Elworthy suggests a preliminary course of bromides followed by tonics. Strychnine, nux vomica, quinine, and iron are often prescribed with success. The general bodily health should be attended to, but little else can be done. Formic acid has been recommended

by Percival (79) in doses of 5 minim of a 25 per cent. solution, but in the same review in which this notice appeared was one from Ohleman (74, p. 229), which says that formic acid is of no service for nystagmus. Instillation of atropine into the eyes has been tried without success. Romiée (89) advises the use of a .3 per cent. of eserine three times a day. The correction of refractive errors is of great importance. Clarke (15) calls attention to the great loss of nervous energy which may result from a small error of refraction. He says it is often the smallest error which produces the greatest eye strain. When the nystagmic patient has had his error corrected a great relief in all the subjective symptoms is experienced, but little change is found for some time in the movements of the eyes. Headache is relieved at once, and the man's condition improved.

Folker (44) at the Oxford Ophthalmological Congress said that in his experience correction of the refractive error hastened the recovery.

Tenotomy has been tried without success. Electric stimulation has also been advised, but no definite result has been obtained.

CHAPTER X.

Summary and Conclusions.

MINERS' nystagmus is an occupational disease of the nervous system confined to workers in coal mines. The chief symptom and physical sign is a rotatory oscillation of the eyeballs. The disease occurs in two forms, the latent and the manifest. In the former, the patient has no symptoms, and is unaware that he has nystagmus. The manifest form may be divided into three types—the slight one, where the patient has little trouble, the ordinary one, in which underground work has to be given up, and the severe one, in which incapacity is complete.

Incapacity.

The incapacity produced by the disease does not depend entirely on the severity of the physical signs present. One man may have violent nystagmus and little incapacity, while another may have marked incapacity and little movement of the eyes. Slight cases can continue to work underground; ordinary cases can work on the surface after a little rest, but severe cases may be permanently incapacitated from producing any work of marketable value. The ordinary cases generally return to work underground after six to 12 months.

The presence of a superadded neurosis has a marked influence on the course of the disease, making the prognosis much worse.

Incidence of the Disease.

The incidence of the disease has been estimated from 10 to 24 per cent. of all underground workers, but the manifest form occurs only in the proportion of .05 to 2 per cent., according to the locality.

Cost to the Country.

The cost of the disease is at least £100,000 a year.

The Views of the Causation of the Disease.

The disease was first described 10 years after the general introduction of the safety lamp in 1851, and is still chiefly found in those mines in which such lamps are used. There have been two chief views with regard to the causation of the disease: (1) That it is due to the position assumed by the worker, necessitating an upward direction of vision and a cramped attitude of the body; (2) That it is due to the strain of working in a deficient light. The first explanation has, until recently, received the most support. The arguments for and against these respective views will be very briefly summarised.

1. THE POSITION HYPOTHESIS.

For.

Nystagmus is often only brought out when the eyes are directed upwards.

The men who hole much, and who have consequently to direct their eyes obliquely upwards, are the men chiefly affected by the disease.

Firemen, who have to direct their eyes upwards to examine the roof, are often affected.

Against.

Holing in naked light pits does not produce nystagmus.

An upward direction of vision is not necessary or usual in holing.

It is the movements of the eyes, and not the muscles of elevation, that are affected.

2. THE DEFICIENT LIGHT HYPOTHESIS.

The disease was unknown before the introduction of the safety lamp.

With improvement of illumination the incidence of the disease diminishes.

The disease is practically unknown in naked light districts. In Scotland, where naked lights are used three times more frequently than in the rest of the kingdom, nystagmus is four times less common.

The skilled workman—the man most subject to eye strain—is more often affected than men from the other grades. In my series of 600 consecutive cases, 577 had used safety lamps and 23 candles. Of these 23 cases, 14 had at one time used safety lamps.

CONDITIONS DETERMINING THE OCCURRENCE OF THE DISEASE.

Age.

The older the worker the more likely is he to suffer from the disease. In my series the average age at onset was 39·37 years, and the mean period of underground life before the onset of symptoms was 25·94 years.

Occupation.

The men who work at the coal face are chiefly affected, but no class of underground worker is exempt.

Method of Work.

Holing alone has apparently no influence on the production of the disease, except when carried out in an insufficient light. Purely naked light districts in which holing is common are free from the disease.

Lights Used.

The naked light pits are comparatively free from the disease, and I have been able to show (1) that the illumination at the face in naked light pits is generally five times as great as that obtaining in the safety lamp pit; (2) that the incidence of the disease in the naked light pits is about $\frac{1}{6}$ of that in the safety lamp pits when the number of men employed is considered; (3) that the frequency of the disease in one large district varies inversely with the light given by the lamps at the individual collieries; (4) that the amount of light falling on the coal face in a steam coal pit is very small, and is often only $\frac{1}{70}$ of a foot-candle.

The Personal Factor.

Men working under precisely similar circumstances are attacked unequally, some men suffering from the disease and others escaping. I have examined men who have worked underground for over 60 years without showing any signs of nystagmus, and yet a case may develop the disease within six months. This personal equation has been overlooked in the past, and it is probable that this is the determining factor of the disease.

Error of refraction was present in 83 per cent. of all cases examined. It must be remembered, however, that 70 per cent. of the general population suffer from error of refraction. The question of colouring should not be lost sight of, and my figures go

to prove that nystagmus is more common in the fair type of man. Accidents to the eyes and head have a marked influence in converting a latent into a manifest attack, while grave injuries to the body generally, and the debilitating effect of ill health, are also potent factors.

Diagnosis.

The diagnosis is made by noting the presence of rotatory oscillation of the eyeballs, and this movement is most easily brought out by asking the patient to elevate his eyes.

Prognosis.

The prognosis depends on the age, length of symptoms before failure, degree of elevation necessary to produce movement, visual acuity, presence of error of refraction, and the presence of absence of tremor of the head. Slight cases recover quickly, ordinary cases in 12 months, and severe cases very slowly and incompletely. An attack of nystagmus should not necessarily be taken as a bar against underground work in the future.

The disease is one of great complexity, and one in which many factors are at work. The chief factor is the ocular strain caused by the deficient light. Error of refraction, deficiency of retinal pigment, position assumed at work, accident and ill-health, are all factors of less importance. The ultimate cause of nystagmus is an inco-ordination of the associated movements of the eyes, the result of imperfect impulses passing to the mid-brain ocular centre.

Preventive Measures.

The preventive measures advocated consist in improving the candle-power of the safety lamp, presumably best by the introduction of electric lamps. In the meantime the greatest care should be taken to maintain the efficiency of the present lamp by careful cleaning and the carrying out of the necessary repairs. The light could also be improved by the use of suitable reflectors. The compulsory use of shades at the back of the lamp during the journey of the miner to and from the coal face is strongly advocated.

The ventilation of the mine should be carefully attended to, as otherwise the lamps will not burn well.

The elimination of unfit workmen by examination of their sight is also advisable.

Appendix.

THE LAW RELATING TO COMPENSATION FOR INCAPACITY DUE TO NYSTAGMUS.

DOUGLAS KNOCKER,

M.B. (Lond.), M.R.C.S. (Eng.), L.R.C.P. (Lond.), D.P.H. (Lond.).

Of the Middle Temple and South-Eastern Circuit, Barrister-at-Law.

Editor of "Accidents in their Medical Legal Aspect," of "Digest of Workmen's Compensation Cases," and Joint Editor with His Honour Judge Ruegg, K.C., of "Butterworths' Workmen's Compensation Cases."

BEFORE the Workmen's Compensation Act, 1906, was extended to nystagmus, this disease, though it incapacitated a workman for ever from following the employment which caused it, was no ground for any claim for compensation or damages either at Common Law or under any statute.

The Workmen's Compensation Act, 1906, as it was passed, did not deal with nystagmus, though it did provide for the payment of compensation, under certain conditions, when disability occurred from a "disease due to the nature of any employment in which the workman was employed at any time within twelve months previous to the date of disablement,"¹ provided that it was a disease "mentioned in the Third Schedule to this Act."¹

The Third Schedule is divided into two columns—the first setting out certain diseases or injuries, the second being a list of occupations specially selected as likely to cause such diseases; nystagmus was not in the schedule. The Secretary of State is, however, empowered to make orders "for extending the provisions of this section to other diseases and other processes,"² and on May 22, 1907, he ordered nystagmus to be included within the Act.

Once a scheduled disease (in this case nystagmus), and total disablement due to it, are established, the workman is in this position, that "he or his dependants shall be entitled to compensation under this Act as if such disease . . . were a personal injury by accident."³

Before a successful claim can be made, certain things must be proved by the workman. Firstly, that one of three things must

¹ Section 8 (1).

² Section 8 (6).

³ Section 8 (1).

have happened—either (*a*) that the Certifying Surgeon of the district in which the workman was employed has certified that he is suffering from a disease mentioned in the Third Schedule (*i.e.*, nystagmus); or (*b*) that the workman has been suspended under rules made under the Factory and Workshops Act, 1901, on account of having contracted such a disease; or (*c*) that he has died from such a disease. The date of the disablement is fixed by the death, suspension, or by the Certifying Surgeon in his certificate; if the certificate does not state the date, then the date on which it was granted is taken to be the date.⁴ Secondly, that the disease (*i.e.*, nystagmus) is due to the nature of the employment in which the workman was employed at any time within twelve months previous to the date of the disablement.

The nature of nystagmus makes it unnecessary for us here to consider any other points of the first group than those which arise in connection with the Certifying Surgeon's certificate.

Certifying Surgeon's Certificate.

The workman cannot recover compensation unless he produces to the Court a certificate, which may be either that of the Certifying Surgeon, or, as mentioned below, of the Medical Referee.

The procedure for examination for the certification by the Certifying Surgeon and for appeals to the Referee, with the special forms fixed for the various steps and certificates, are all to be found in the Regulations for Certifying Surgeons, &c., drawn up by the Secretary of State under the authority of Section 8 (1) (3), and made on June 21, 1907, and amended up to date.

The workman in applying has to supply certain information which includes the symptoms of which he complains, the name of the disease (*i.e.*, nystagmus), the employment to which it is attributable, and the name and place of business of his last employer.⁵

The Scottish Courts decided in *Taylor v. Burnham and Co.*⁶ that the certificate need not be obtained before the commencement of the arbitration proceedings, though clearly it must be obtained before the actual award can be made in the case.

To obtain the certificate the workman must submit himself to

⁴ Section 8 (4).

⁵ Certifying Surgeons' Regulations, Schedule, Form 1.

⁶ [1909] S.C., 704; 46 S.C., L.R., 482; 2.B.W.C.C., 247.

examination by the Certifying Surgeon of the "District in which" he "is employed."⁷ If there is no such surgeon, then the workman cannot obtain a certificate and so cannot recover compensation. This point does not arise in connection with nystagmus, but has arisen in other industrial diseases occurring in such workmen as sailors, whose employment and disablement was in mid-ocean, for which "District" there is no Certifying Surgeon. *CURTIS v. BLACK*.⁸

The Certifying Surgeon, on payment of a small fee, must examine and give a certificate stating whether or not the man's claim is justified. The fee is fixed by the rules at 1s., if the surgeon examined the man in the course of his duties under the Factory and Workshop Act, and in all other cases at 5s.⁹ If the Certifying Surgeon certifies that the man has the disease (nystagmus) he must state what are the leading symptoms present upon which his conclusion was based.¹⁰

If the certificate is granted, the employer, within seven days of his receipt of a copy of the certificate, can appeal to the Medical Referee of the district, and alternatively if the certificate is refused the workman can appeal to him; this appeal must be made by the workman within seven days of the refusal.¹¹ The Referee can agree or disagree with the Certifying Surgeon, and his decision is final on the point of the presence or absence of the disease (nystagmus).¹²

Appeal to the Referee is made by application to the Registrar of the district within the period mentioned above, who can for good reason extend the time for appealing a further seven days. The application must be made in writing.¹³

Both parties can also send the Referee copies of any reports obtained from any medical practitioner who has examined the diseased workman either on behalf of the workman or the employer. The employer also has to undertake to pay any necessary travelling expenses incurred by the workman in order

⁷ Section 8 (1).

⁸ (1909) 2 K.B., 529; 78 L.J., K.B., 1022; 100 L.T., 977; 25 T.L.R., 621; 53 Sol. J., 576; 2.B.W.C.C., 239.

⁹ Certifying Surgeons' Regulations 7.

¹⁰ Certifying Surgeons' Regulations, Schedule, Form 3, Certificate of Disablement.

¹¹ Section 8 (1) (f) and Certifying Surgeons' Regulations 8.

¹² Section 8 (1) (f).

¹³ Certifying Surgeons' Regulations, Schedule, Form 9 or 10.

that he may submit to this examination, the amount of which can be fixed, if necessary, by the Registrar.¹⁴

A fee of 2 guineas is payable for this examination.¹⁵

The Registrar sends copies of all documents to the Referee and to both parties a copy of the order of reference to the Referee and copies of such papers as the aggrieved party files with his application.¹⁶

The Medical Referee is as a rule the one appointed for the district, but for eye cases there is often a specially appointed Referee to whom such cases must be referred.¹⁷

The Referee notifies both workman and the employer of the time and place for examination, and if the workman or employer does not appear at the place, the Referee can decide on such information as is before him, even, in the case of the absence of the workman, without making any examination.¹⁸

At the examination either party can make any statement, and the Referee must hear it.¹⁹

The Referee notifies the result of his examination on a proper form,²⁰ a copy of which he sends to the Registrar and both parties.

Where any special difficulty arises, the Medical Referee may apply for assistance from the Secretary of State, who may, if he thinks fit, grant such assistance.²¹

This decision is final as to the presence or absence of the disease.²²

Nystagmus due to the Nature of the Employment.

If the certificate states that the workman has nystagmus, and if "At, or immediately before, the date of the disablement . . ." he "was employed in any process mentioned" opposite it "in the second column of the Third Schedule," (*i.e.*, mining) "the disease" (*i.e.*, nystagmus) "shall be deemed to have been due to the nature of the employment, unless the employer proves the

¹⁴ Certifying Surgeons' Regulations 9.

¹⁵ Certifying Surgeons' Regulations 18.

¹⁶ Certifying Surgeons' Regulations 12.

¹⁷ Certifying Surgeons' Regulations 13.

¹⁸ Certifying Surgeons' Regulations 13.

¹⁹ Certifying Surgeons' Regulations 15.

²⁰ Certifying Surgeons' Regulations Schedule, Form 15.

²¹ Certifying Surgeons' Regulations 18 (iii).

²² Section 8 (ii) (f).

contrary.”²³ The employer has to accept the most difficult of all positions, that of proving a negative. If the Certifying Surgeon, however, certifies, either in the certificate or separately, that in his opinion the disease was not due to the nature of the employment,²⁴ this merely shifts the burden of proof from the shoulders of the employer back onto those of the workman. The part of the section which says “the decision shall be final”²⁵ only refers to the *presence* of the disease (nystagmus), and does not mean that the workman cannot go on and prove that the surgeon or referee in the certificate expresses an erroneous opinion as to the *cause* of the nystagmus. At least, this has been held to be law in Scotland, and there is no doubt the English Court of Appeal would agree with the Scottish Court of Session. See *M'GINN v. UDSTON COAL COMPANY LIMITED*, quoted on p. 147.

Where the workman obtains a certificate that he has the disease (*i.e.*, nystagmus) mentioned in the first column, but was not engaged in a process (*i.e.*, mining) opposite it in the second column, but was engaged in some other work, he can still go on, but he then will have to prove that the particular work upon which he was engaged did, in fact, produce nystagmus.

Defences.

SPECIAL DEFENCES, *i.e.*, THOSE SPECIAL TO INDUSTRIAL DISEASES.

Compensation is recoverable primarily from the employer who last employed the workman during the twelve months preceding the incapacity in the employment to which the incapacity was due, unless that employer can shift the responsibility to another employer.²⁶

If he has been employed for any less period by that employer, then the employer is entitled to prove that the disease was not contracted in his employment, but in another employer's employment, and that other employer may be joined in the proceedings by the last employer and found liable.²⁷ For this purpose the workman must inform the employer of any other

²³ Section 8 (2).

²⁴ Section 8 (2).

²⁵ Section 8 (1) (*f*).

²⁶ Section 8 (1) (*c*) and (*e*).

²⁷ Section 8 (2) (*c*).

employers under whom he has worked during the twelve months preceding.²⁸ If this information is not furnished, the last employer, by proving that the employment under him did not cause the incapacity, can entirely escape liability.

If the workman has wilfully and falsely represented himself in writing as not having previously suffered from the disease, compensation shall not be payable.²⁹ This is particularly important in the case of nystagmus, because if the disease is one which is acquired by a gradual process, as is the case with nystagmus, the employer, where he has employed the man for less than twelve months, may claim contribution for the part of the gradual process which is due to the other employer's employment if he can prove that their work also contributed to it.³⁰ For an example of this see *MORRIS v. THE NAVAL COLLIERY COMPANY LIMITED*, reported on p. 148.

GENERAL DEFENCES.

In addition to the special defences available on claims for compensation for industrial disease, with the exception that he cannot deny the presence of nystagmus, the employer can use every other defence which would be available to him had the case been any ordinary injury. He can in his "answer" deny that the nystagmus was acquired when the workman was working with him—that is, he can prove that the disease "is not due to the nature of the employment under him," though, as we have already mentioned here, he is in a worse position than in an ordinary case, for unless the Certifying Surgeon certified that the employment did *not* cause the disease, the usual positions are reversed. For in nystagmus occurring while mining, the employer has to prove that the disease was *not* acquired while in his employment, while in an ordinary case of disease the workman has to establish his claim and prove that it was due to the nature of the employment. In other respects there is nothing special in these cases of nystagmus, except that, owing to the method employed to light the mine, the particular employer may be able to prove that the miner would not have been likely to acquire the disease when employed by him. (See Chapter V.) Malingering, recovery, or other disease such as disseminated sclerosis and other conditions producing nystagmus

²⁸ Section 8 (1) (c).

²⁹ Section 8 (1) (b).

³⁰ Section 8 (1) (c) (iii).

may afford the employer a good defence. See *LISTER KAYE v. MOOREHOUSE*; *JONES v. NEW BRYNMALLY COLLIERY COMPANY*; and *M'GINN v. UDSTON COAL COMPANY LIMITED*, quoted on pp. 146-148.

The employer may also rely upon the defences that notice or claim was not given or made within the proper times.

Written notice of the disablement must be given "as soon as practicable after the happening thereof," and the only way the workman can escape from this is by proving that the employer was not prejudiced in his defence by the delay in giving notice or that the delay was due to "mistake, absence from the United Kingdom, or other reasonable cause."³¹ Here it must not be overlooked that the workman has to prove that the employer was not prejudiced; the law is not that the employer has to prove he was prejudiced. Notice must be in writing, though claim can be oral. The fact that notice has been given verbally to the employer himself or his duly appointed agent, however, is some evidence that the employer has not been prejudiced by delay in or want of written notice.

Claim for compensation must be made within six months, and again, the workman can only avoid the consequence of delay by showing that such delay was due to a "mistake, absence from the United Kingdom, or other reasonable cause."³²

Of these defences, proof that the employer was not prejudiced by delay of notice (which defence does not apply to delay of claim) is a pure question of fact, of which the evidence would probably be entirely medical in the case of nystagmus. Ignorance of the law or its necessary formalities is not "mistake or reasonable cause," but there have been many cases on what is reasonable cause for delay, the usual one being that the workman was not aware of the serious effects of the injury. The opinion that the nystagmus would soon pass off may be "reasonable." This was so held in one case of nystagmus where the man thought he would soon get well, and delay occurred in making a claim within six months of the disablement. The date of disablement was fixed by the certificate to a date more than six months prior to the examination; and as this dating back was by the Certifying Surgeon, it was held that

³¹ Section 2 (1), proviso (a).

³² Section 2 (1), proviso (b).

there was further reasonable cause for delay. *See* MOORE *v.* NAVAL COLLIERY COMPANY, quoted on p. 145.

Cessation of Incapacity.

The employer who has paid compensation or admitted liability up to a certain date can set up the defence or claim release from further liability on the ground that the man has now recovered. By recovery is meant that the workman is able to earn as much as he did before the accident. If he is able to earn, at his old work, as much as before the accident and has completely recovered, without serious risk of recurrence, the judge must terminate the employer's liability to pay compensation. But the question of recurrence must be considered, especially in nystagmus, for though the workman has, in fact, returned to his old work, and is, in fact, earning his old wages, there is sometimes a probability of the disease soon returning if he works long under the old conditions. In these cases the judge must make an "open award," *i.e.*, he does not order the employer to pay any compensation at present, but makes an award so worded that the workman, as soon as the incapacity returns, can again claim from the employer. There are two decided cases which appear conflicting on this very point, and they differ simply and solely because the proper evidence was not before the county court judge. In JONES *v.* NEW BRYNMALLY COLLIERY COMPANY LIMITED, quoted on p. 146, there was no evidence in fact given before the county court judge that nystagmus, after a previous attack due to mining, would be more likely to recur on return to mining than it would have been had the miner not had this attack, and the Court of Appeal held that no compensation could be awarded, as there was no evidence that the tendency to recurrence had been aggravated by this attack. In another case, GARNANT ANTHRACITE COLLIERY LIMITED *v.* REES, quoted on p. 146, this evidence was forthcoming, namely, that the previous attack of nystagmus which was due to the work would render the miner more susceptible to future attacks, so he was entitled to compensation.

In other respects the procedure under the Workmen's Compensation Act, 1906, connected with a claim for compensation for nystagmus is identical with a claim for personal injury by accident.

Sub-sections (1) to (5) of section 8 of the Workmen's Compensation Act, 1906, are here quoted in full. The reader may replace the word "disease" by "nystagmus."

8.—(1) Where—

- (i) the certifying surgeon appointed under the Factory and Workshop Act, 1901, for the district in which a workman is employed certifies that the workman is suffering from a disease mentioned in the Third Schedule to this Act and is thereby disabled from earning full wages at the work at which he was employed; or
- (ii) a workman is, in pursuance of any special rules or regulations made under the Factory and Workshop Act, 1901, suspended from his usual employment on account of having contracted any such disease; or
- (iii) the death of a workman is caused by any such disease;

and the disease is due to the nature of any employment in which the workman was employed at any time within the twelve months previous to the date of the disablement or suspension, whether under one or more employers, he or his dependants shall be entitled to compensation under this Act as if the disease or such suspension as aforesaid were a personal injury by accident arising out of and in the course of that employment, subject to the following modifications:—

- (a) The disablement or suspension shall be treated as the happening of the accident;
- (b) If it is proved that the workman has at the time of entering the employment wilfully and falsely represented himself in writing as not having previously suffered from the disease, compensation shall not be payable;
- (c) The compensation shall be recoverable from the employer who last employed the workman during the said twelve months in the employment to the nature of which the disease was due:

Provided that—

- (i) the workman or his dependants if so required shall furnish that employer with such information as to the names and addresses of all the other employers who employed him in the employment during the said twelve months as he or they may possess, and, if such information is not furnished, or is not sufficient to enable that employer to take proceedings under the next following proviso, that employer upon proving that the disease was not contracted whilst the workman was in his employment shall not be liable to pay compensation; and

(ii) if that employer alleges that the disease was in fact contracted whilst the workman was in the employment of some other employer, and not whilst in his employment, he may join such other employer as a party to the arbitration, and if the allegation is proved that other employer shall be the employer from whom the compensation is to be recoverable ; and

(iii) if the disease is of such a nature as to be contracted by a gradual process, any other employers who during the said twelve months employed the workman in the employment to the nature of which the disease was due shall be liable to make to the employer from whom compensation is recoverable such contributions as, in default of agreement, may be determined in the arbitration under this Act for settling the amount of the compensation ;

(d) The amount of the compensation shall be calculated with reference to the earnings of the workman under the employer from whom the compensation is recoverable ;

(e) The employer to whom notice of the death, disablement, or suspension is to be given shall be the employer who last employed the workman during the said twelve months in the employment to the nature of which the disease was due, and the notice may be given notwithstanding that the workman has voluntarily left his employment.

(f) If an employer or a workman is aggrieved by the action of a certifying or other surgeon in giving or refusing to give a certificate of disablement or in suspending or refusing to suspend a workman for the purposes of this section, the matter shall in accordance with regulations made by the Secretary of State be referred to a medical referee, whose decision shall be final.

(2) If the workman at or immediately before the date of the disablement or suspension was employed in any process mentioned in the second column of the Third Schedule to this Act, and the disease contracted is the disease in the first column of that Schedule set opposite the description of the process, the disease, except where the certifying surgeon certifies that in his opinion the disease was not due to the nature of the employment, shall be deemed to have been due to the nature of that employment, unless the employer proves the contrary.

(3) The Secretary of State may make rules regulating the duties and fees of certifying and other surgeons (including dentists) under this section.

(4) For the purposes of this section the date of disablement shall be such date as the certifying surgeon certifies as the date on which

the disablement commenced, or, if he is unable to certify such a date, the date on which the certificate is given. Provided that—

- (a) Where the medical referee allows an appeal against a refusal by a certifying surgeon to give a certificate of disablement, the date of disablement shall be such date as the medical referee may determine:
- (b) Where a workman dies without having obtained a certificate of disablement, or is at the time of death not in receipt of a weekly payment on account of disablement, it shall be the date of death.

(5) In such cases, and subject to such conditions as the Secretary of State may direct, a medical practitioner appointed by the Secretary of State for the purpose shall have the powers and duties of a certifying surgeon under this section, and this section shall be construed accordingly.

Nystagmus was added to the schedule of industrial diseases by Order of the Secretary of State, dated May 22, 1907.

THIRD SCHEDULE.

Description of Disease or Injury.	Description of Process.
(1)-(11) (12) Nystagmus (13)-(20)	Mining

COURT OF APPEAL. ENGLAND.—October 15, 1911.

MOORE v. NAVAL COLLIERY COMPANY LIMITED.

Notice and claim—Delay in hope of cure—Industrial disease—Certifying Surgeon's certificate dates "accident" six months back.

"A collier had suffered from nystagmus for years. He had been advised by his doctor that if he gave up underground work he would get better. In the middle of 1910 his eyesight was getting worse, but, as a strike was threatening which was likely to last long, and he hoped that the spell above ground would cure him, he refrained from claiming compensation or getting a certificate of disablement. He did his full work until the strike, which began on September 3, 1910, and lasted till after the hearing of this case. His eyesight did not get better, and ultimately, on March 7, 1911, he obtained a certificate, which fixed the date of disablement as September 3, 1910. He then gave notice of accident and brought proceedings; the employers objected that notice and claim had not been given and made in accordance with the Act. The county court

judge held that the delay in claim was not due to a reasonable cause, and awarded for the employers.

"*Held*, the delay was due to reasonable cause, and the case must be remitted for assessment of compensation."

(1912) 1, K B. 28; 81, L.J., K.B. 149; 105, L.T. 838; 5 B.W.C.C. 87; C.A., Oct. 18, 1911.

COURT OF APPEAL. ENGLAND.—*March 29, 1912.*

JONES *v.* NEW BRYNMALLY COLLIERY COMPANY LIMITED.

"*Where . . . incapacity . . . results*"—"From a disease mentioned in Schedule III."—Coalminer predisposed to nystagmus—Two different attacks—Complete recovery from each attack—Risk of recurrence on

COURT OF SESSION, SCOTLAND.—March 8, 1912.

MCGINN v. UDSTON COAL COMPANY LIMITED.

Certifying surgeon certifies disease not due to employment—Workman only deprived of advantage of presumption, may still prove that disease is due to employment.

“A certifying surgeon certified that a miner was suffering from nystagmus. On appeal from this certificate, the medical referee, in effect, certified that the man was suffering from nystagmus, but that the nystagmus was not due to the nature of the employment. The workman brought proceedings for compensation, but the sheriff-substitute dismissed them on the ground that the proceedings were incompetent, the medical referee having certified that the disease was not due to the employment.

“*Held*, the certificate merely removed the presumption given in favour of the workman by sub-section (2), to the effect that the disease was due to the nature of the employment; it did not bar the proceedings, and it was open to the workman to prove, just as in ordinary cases under sub-section (1), that the disease was in fact due to the employment; case remitted. In giving judgment, the Lord President pointed out that if the disease had been scheduled as ‘miners’ nystagmus’ no difficulty would have arisen.”

[1912] S.C. 668; 49 Sc.L.R., 531; 5 B.W.C.C., 559.

COUNTY COURT AT TREDEGAR.

Before his Honour Judge Owen.

JAMES v. THE RHYMNEY IRON AND COAL COMPANY.

Certificate of the certifying surgeon—Second certificate fixes different date from the first.

James, a miner, obtained a certifying surgeon’s certificate which gave no date for the incapacity, which was, in consequence, fixed as at the date of the certificate—namely, January 9, 1909. The workman was dissatisfied with this, and so he once more applied to the certifying surgeon, who granted a fresh certificate, dating the incapacity back to October 7, 1908, and upon the strength of this he commenced arbitration proceedings. At the hearing the employers objected to this second certificate, and his Honour upheld the objection and awarded compensation to the workman as from January 9 and not as from October 7, 1908.

(Local Papers.)

COUNTY COURT AT PONTYPRIDD.—*September 14, 1909.*

Before his Honour Judge Bryn-Roberts

MORRIS v. NAVAL COLLIERY COMPANY.

Nystagmus—"Contracted by a gradual process"—Contributions from the employers.

Morris, a miner, obtained from the certifying surgeon a certificate which stated that he was suffering from nystagmus. The certificate fixed the date of disablement as February 13, 1909. No appeal was made to the medical referee of the district, and so Morris claimed compensation at the rate of 18s. weekly from his last employers, the Naval Colliery Company, who had paid him 30s. weekly up to the time of his disablement. During the twelve months immediately preceding February 13 Morris had also worked for three other collieries, who were joined by the Naval Colliery Company as third parties on the ground that the disease was of such a nature as to be contracted by a gradual process, and so had been to some degree acquired while working for them. The medical evidence, including that of the certifying surgeon, was that nystagmus was a progressive disease which might take some years to develop.

The judge awarded compensation, finding that the other employers were liable to contribute four-fifths of the total compensation as follows:—The respondents—the Naval Colliery Company, one-fifth; the Powell Duffryn, two-fifths; Nixons Limited, one-fifth; the Lancaster Steam Colliery Company, one-fifth.

(Local Papers.)

COUNTY COURT AT HUDDERSFIELD.—*June 3 1912.*

Before his Honour Judge Longstaffe.

LISTER KAYE (THE EXORS. OF) v. MOOREHOUSE.

Malingering—Artificially producing symptoms of nystagmus.

A collier was certified to be suffering from miners' nystagmus, and received compensation in respect thereof for three years. The employers then filed an application to review and terminate the payments on the ground that the man had completely recovered, and that his then condition was due to his deliberately producing artificially the symptoms of nystagmus. After hearing the medical evidence, his Honour said that he was convinced that the man could control and also aggravate all the symptoms of nystagmus and make the disease last longer than it otherwise would, and that he was malingering or unduly and improperly prolonging the duration of the disease. At the same time, as he was still suffering to some extent from the disease, he would not terminate the compensation absolutely, but reduced it to 1d a week.

(Local Papers.)

Glossary.

Accommodation.—The alteration in the focal length of the lens which is brought about by muscular action. (*See* p. xviii.)

Ametropia.—Deficient vision.

Astigmatism.—An eye is astigmatic when the horizontal and vertical curvatures of the cornea are unequal.

Brain Centres.—Highly specialised parts of the brain which regulate muscular movements or act as receiving stations for sensations from without. They may be compared with the switch-board of a telephone service.

Candle-power.—The standard measurement. A standard candle burns 120 grains of sperm every hour, and is said to be of 1 candle-power.

Cerebellum.—The small brain or part of the brain intimately connected with equilibration.

Conjunctiva.—The lining membrane of the eyelids which is reflected over the white part of the eye (sclerotic), and becomes continuous with the superficial layers of the cornea.

Convergence.—A turning of the eyes towards each other.

Co-ordination.—Regular muscular action. The movements of the legs in walking are co-ordinate, but become inco-ordinate in drunkenness.

Cornea.—The transparent part of the front of the eye.

Diopter.—A lens of 1 metre focal length is said to be of 1 diopter.

Diplopia.—Double vision.

Downcast Shaft.—Every pit has two shafts, one which admits fresh air—the downcast shaft—the other through which the air returns to the surface—the upcast shaft.

Emmetropia.—Normal vision.

Error of Refraction.—Departure from normal vision, the result of anatomical changes in the eye.

Fixation.—We use direct fixation when we look straight at any object. If the object is seen out of the corner of the eye it is seen by indirect fixation.

A Foot-candle is the illumination produced by 1 candle-power at a distance of 1 ft.

Fovea.—That part of the retina opposite the central points of the cornea and lens.

Gas Cap.—The pale blue flame which appears on the top of a turned down safety lamp flame in the presence of gas.

Holing.—A process by which the collier undercuts the coal. (*See* p. 42).

Heterophoria.—A latent squint. (*See* p. xvi.)

Hyperphoria.—A latent squint in the upward direction.

Hypermetropia.—Long sight. (*See* p. xvii.)

Intake.—The main road leading from the downcast pit shaft to the workings and containing fresh air.

Iris.—The coloured part of the eye.

Iritis.—Inflammation of the iris.

Labyrinth.—The part of the inner ear associated with the maintenance of equilibrium.

Mid-brain.—The portion of the brain which connects the higher brain with the lower brain, a part directly continuous with the spinal cord.

Myopathy.—A wasting of muscles.

Myopia.—Short sight. (*See* p. xvii.)

Neurasthenia.—Lack of nerve strength.

Neurosis.—An affection of the nervous system without any structural change. (*See* p. 22.) A functional disease of the nervous system.

Nictitation.—Blinking of the eyelids. Clonic spasm of the eyelids.

Night Blindness.—Inability to see in the dark or at dusk.

Perifoveal.—The region of the retina outside of and around the fovea.

Photophobia.—Fear or dread of light. The patient is unable to look at a bright light.

Photopsia.—Subjective sensations of flashes of light.

Pons.—A part of the lower brain.

Ptosia.—A drooping of the upper eyelid.

Reflex Action.—An involuntary response of a muscle to peripheral stimulation. If, for example, a hot cinder falls on a hand, that hand is at once drawn away by an involuntary action before the subject is aware that he is burnt. This involuntary withdrawal is due to reflex action of the muscles in response to the painful peripheral stimulation.

Retina.—A complicated membrane lining the inside of the eye and sensitive to light.

Return.—The road coming from the workings to the upcast pit shaft and containing air after it has been through the whole pit.

Sclerotic.—The tough outer white coat of the eye which blends in front with the cornea. It is covered by the conjunctiva.

Scotopia.—Vision in dull illumination. (*See* p. 112.)

Sign.—A phenomenon of a disease usually *objective* in character—*i.e.*, observed by the *physician* in distinction from that observed by the patient.

Surface Brightness.—The amount of light reflected from a surface. (*See* p. 64.)

Symptom.—A phenomenon of a disease usually *subjective* in character, *i.e.*, observed *only by the patient*. A symptom may also be a sign, *e.g.*, a man may complain of movement of the eyes, and this movement may be seen by the physician.

Visual Acuity.—The amount of vision possessed. (*See* p. xviii.)

Visual Purple.—A pigment found in the deep layers of the retina and sensitive to light. (*See* p. xviii.)

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THE EFFECTS OF DEFICIENCY OF OXYGEN ON THE LIGHT OF A SAFETY LAMP.*

By J. S. Haldane, M.D., LL.D., F.R.S., and T. Lister Llewellyn, M.D.

THE observations now to be described were made in the Physiological Laboratory, Oxford, in an air-tight chamber of a capacity of about 70 cubic feet, the air being allowed to become vitiated by the respiration of the observer inside and the burning of oil in the lamp. In this way a vitiation was produced similar to what occurs in a mine through formation of blackdamp. The experiments were made as follows:—One observer went into the chamber with the photometer, a safety lamp, dry and wet bulb thermometers, and an electric fan for keeping the air thoroughly mixed and causing a current of air to play over the thermometers. Through the wall of the chamber a capillary glass tube was passed, connected with the burette of the larger form of Haldane gas-analysis apparatus, and through this tube the other observer took samples of the air for analysis, simultaneously with the photometer and thermometer readings. The lamp used was an ordinary Patterson safety lamp, burning a mineral oil of flash point 260 degs. Fahr.; and the photometer was the form of Trotter photometer used by Dr. Llewellyn in all his experiments, the readings being standardised, just before the experiments, against a Board of Trade standard candle. After the initial observations had been made with the door wide open and fan running, the door was closed air-tight and observations made at intervals until the lamp was finally extinguished by the vitiated air. From the time when the door was closed about two hours were required for this.

In the first set of observations the flame was set to the height customary when lamps are supplied at a lamp room, the height being well below the point at which smoking begins; and throughout the observations the flame was not regulated in any way. The results are shown in Table I. The door was closed at about 12.5, and the lamp went out at 2.3 p.m.

*Extract from a paper read before The Institution of Mining Engineers.

TABLE 1.—FIRST SET OF OBSERVATIONS.

Time.	Light, in candles.	Percentage of		Temperature.		Calculated percentage of moisture by volume.
		Oxygen.	Carbon- dioxide.	Dry bulb.	Wet bulb.	
				Degs. F.	Degs. F.	
11:50	0.405	20.90	0.05	65.3	56.3	1.15
12:13	0.37	20.66	0.25	69.0	59.2	1.25
12:28	0.315	20.34	0.52	70.7	65.3	1.8
12:43	0.27	19.88	0.88	72.5	67.1	1.8
1:3	0.17	19.34	1.26	74.3	69.0	2.0
1:23	0.11	18.92	1.71	75.6	70.2	2.2
1:45	0.045	18.28	2.17	77.0	73.2	2.5
2:3	0.00	18.01	2.40	77.0	75.2	2.8

To render their results more readily intelligible, the writers have prepared Table 2, showing the observed percentage diminution of the light with observed percentage diminutions of the oxygen.

TABLE 2.—OBSERVED PERCENTAGE DIMINUTION OF LIGHT WITH
OBSERVED PERCENTAGE DIMINUTION OF OXYGEN.

Light given.	Oxygen percentage.	Light percentage diminished.	Oxygen percentage diminished.
100	20.93	0	0.00
90	20.66	10	0.27
77	20.34	23	0.59
66	19.88	34	1.05
41	19.34	59	1.89
27	18.92	73	2.01
11	18.28	89	2.65
0	18.01	100	2.92

It will be seen that, roughly speaking, every diminution of 0.1 per cent. in the oxygen caused a diminution of 3.5 per cent. of the value of the light in pure air, or for every 10 per cent. of diminution in the value of the light in fresh air there was a diminution of about 0.29 per cent. in the oxygen. With the oxygen reduced to 19.0 per cent., the minimum percentage allowed by the Coal Mines Act for purposes of ordinary work, the light would be diminished by 70 per cent. under the conditions of the experiment.

Under practical conditions in a mine, the flame of a lamp will nearly always be turned p more or less, when the light begins to fail, owing

to bad air. Probably the flame will be turned up to about the smoking point, and for a time a better light will thus be obtained, although the light will soon begin to fail again, owing to smoking of the glass, clogging of the gauze, and crusting of the wick.

To obtain some idea of the effects of turning up the flame, the writers made a second series of experiments, starting with the flame turned up to just under the visible smoking-point and afterwards turning up the flame at intervals, so as to get about the maximum amount of light despite of some smoking. At the end of the series, when the flame finally left the wick and was extinguished, the air of the chamber was smoky and unpleasant, and the wick much crusted. The results are shown in Table 3. The door was closed at 5.57.

TABLE 3.—SECOND SERIES OF EXPERIMENTS.

Time.	Light in candles.	Percentage of		Temperature.		Calculated percentage of moisture by volume.
		Oxygen.	Carbon dioxide	Dry bulb.	Wet bulb.	
5.50	0.585	20.92	0.05	Degs. F. 64.7	Degs. F. 57.2	1.3
6.12	0.45	20.46	0.36	70.7	65.3	1.75
6.38	{ 0.32 0.45* }	19.79	0.95	73.4	69.0	2.1
6.53	{ 0.38 0.45 }	19.35	1.28	75.2	70.0	2.2
7.13	0.41*	18.84	1.74	76.0	71.6	2.3
7.33	0.25*	18.33	2.14	76.5	73.4	2.5
7.48	0.18*	17.89	2.44	—	—	—
8.5	0.00	17.48	2.77	77.0	75.2	2.8

* Flame raised to optimum just before photometer reading.

It will be seen from these observations that by raising the wick (1) the flame was made to last until the oxygen fell to 17.48, or 0.53 per cent. lower than in the previous experiment; (2) the light could be increased to 70 per cent. of its initial value in spite of a fall in the oxygen percentage to 18.84, at which point the light would only have been about 25 per cent. of the initial value had the flame not been adjusted. Probably, however, the light would not have lasted long at its improved value if the oxygen had remained steady. The wick was crusting rapidly, and at the end of the experiment was much above the metal holder. Up to the third observation the wick was not turned up any higher than at first; and the light had fallen proportionally more than in the first experiment for the same oxygen percentage.

TEST MADE ON ONE "C.E.A.G." LAMP.

Accumulator freshly charged gave 2 volts. The lamp was kept alight for ten hours. Average photometric reading through first three hours

·8 candle-power.

At the end of the tenth hour of continuous use the reading was

·65 candle-power.

A tested standard candle gave readings varying from ·95 to 1 candle-power.

TEST MADE ON ONE OLDHAM'S HEWER'S "SHADOWLESS" ELECTRIC LAMP.

Accumulator freshly charged gave 2 volts. The lamp was kept alight for ten hours. Average photometric reading through first three hours

1·2 candle-power.

At the end of the tenth hour of continuous use the reading was

·85 candle-power.

A tested standard candle gave 1 candle-power.

The accumulator at the end of the test gave less than 2 volts. In front and over half the upper part of the lamp the bulb is only protected by a water jacket between two domed glasses. No bars or ironwork obstruct the light. The back of the outer glass is enamelled white, and this reflecting surface produces an even diffused light, which obviates the glare so constantly found in electric lamps.

Tested in the horizontal direction the lamp gave 1·2 candle-power; at 45 degs. above the horizontal the same candle-power was obtained; at 90 degs. above the horizontal (that is, the light given by the lamp towards the roof) the candle-power was ·9.

